



**THE UNIVERSITY  
OF ILLINOIS  
LIBRARY**

665.7  
P33P  
cop.2

Return this book on or before the  
**Latest Date** stamped below.

University of Illinois Library

DEC 20 1961  
JUN 27 1962

L161—H41





Scale 1/2 inch to a Foot.

F E D C B A A  
 FRONT ELEVATION OF THE GAS WORKS AT BURY ST EDMUNDS, SUFFOLK, ERECTED BY T S PECKSTON, IN 1834.

Thos S Peckston

London, Published by E Hebert 20<sup>th</sup> February 1841.



Scale

B

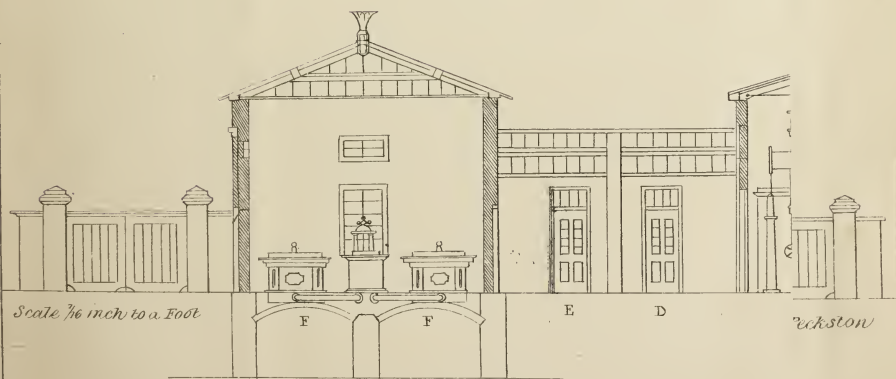
A

A

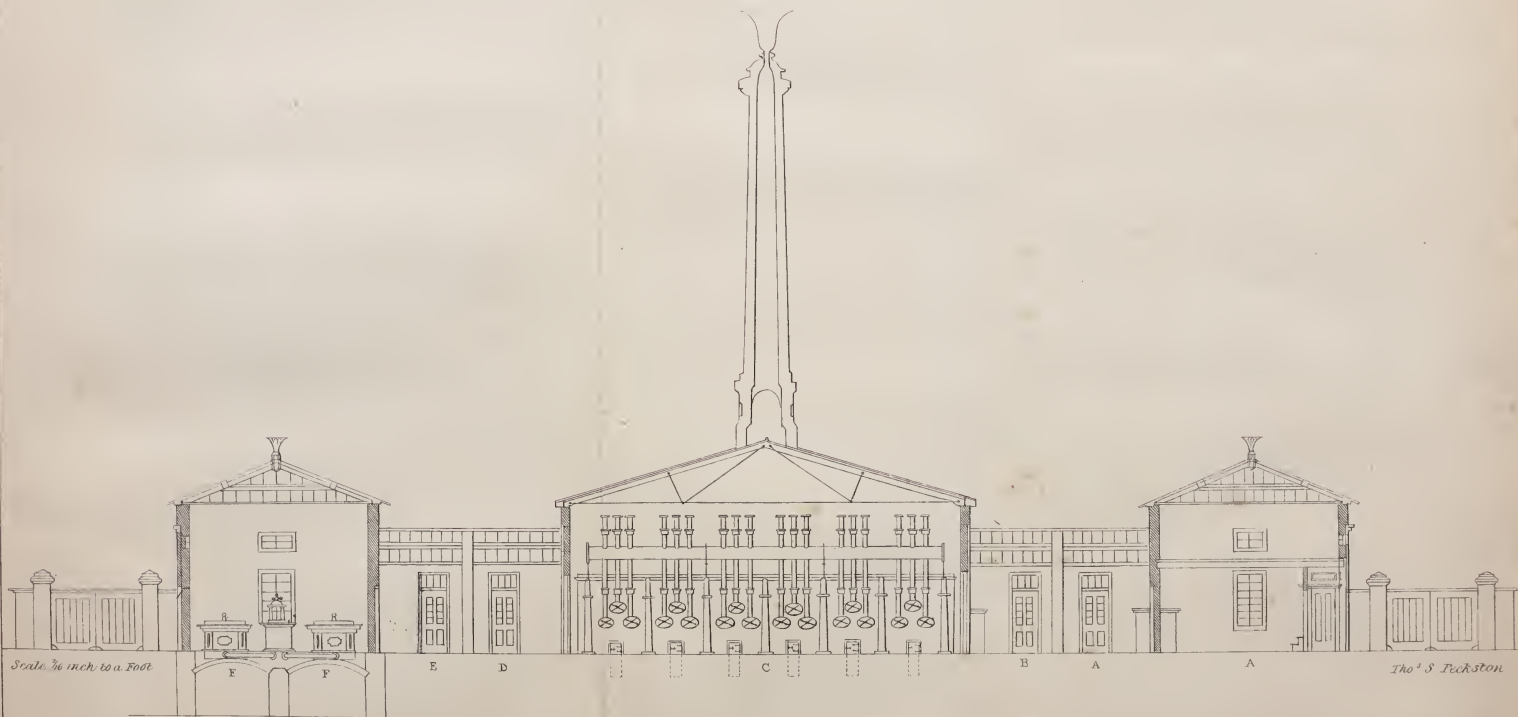
Tho: S. Peckston.

LK, ERECTED BY T.S PECKSTON; IN 1834.

ry, 1841.



TRANSVERSE VERTICAL SECTION OF THE GAS WO



TRANSVERSE VERTICAL SECTION OF THE GAS WORKS AT BURY ST EDMUNDS, SUFFOLK, ERECTED BY T.S. PECKSTON, IN 1834.

London, Published by E. Herbert, 20<sup>th</sup> February, 1841.

A  
PRACTICAL TREATISE  
ON  
G A S - L I G H T I N G ;

IN WHICH THE  
GAS-APPARATUS GENERALLY IN USE IS EXPLAINED  
AND ILLUSTRATED

BY  
TWENTY-TWO APPROPRIATE PLATES.

---

*THE THIRD EDITION,*

CAREFULLY CORRECTED AND ADAPTED TO THE PRESENT IMPROVED  
STATE OF THE MANUFACTURE OF GAS.

---

BY  
THOMAS S. PECKSTON, R.N.,  
CIVIL ENGINEER,

LATE A VICE-PRESIDENT OF THE LONDON MECHANICS' INSTITUTION, AND  
PRESIDENT OF THE MECHANICS' INSTITUTION, DUBLIN,  
&c.      &c.      &c.

LONDON :  
HEBERT, CHEAPSIDE.

---

1841.

LONDON :  
Printed by WILLIAM CLOWES and SONS,  
Stamford Street.

10 My 29 Recd

665.7  
P33p  
cop. 2

THE LIBRARY OF THE  
FEB 20 1929

UNIVERSITY OF ILLINOIS

TO THE HONOURABLE

SIR COURTENAY BOYLE, K.C.H.,

VICE-ADMIRAL OF THE WHITE, &c. &c. &c.

DEAR SIR,

To you I dedicate this, I trust, very much improved Edition of "*A Practical Treatise on Gas-Lighting*," in the same spirit in which I had the pleasure of dedicating to you the two former Editions, as a testimonial of my most grateful acknowledgments for the kindness and attention which you have on all occasions evinced towards me.

I am,

Dear Sir,

With the greatest respect,

Your most obliged

and devoted Servant,

THOMAS SNOWDON PECKSTON.

10, Arundel Street, Strand, London,  
22nd March, 1841.

a 2

677525

~~1859/278707~~



## P R E F A C E.

---

SINCE the former editions of this work were laid before the public, the author has (almost without intermission) been practically engaged in giving plans for gas-works, and superintending their erection in England, Ireland, the Channel Islands, &c. During the progress of his labours, many things suggested themselves to him, having a tendency to simplify and amend the apparatus used for the manufacture of coal-gas, which he considered might be useful to the practical engineer. He therefore determined to introduce the results of his own experience into any future impression of this work that might be called for, and therein not to overlook such improvements as have fallen beneath his notice.

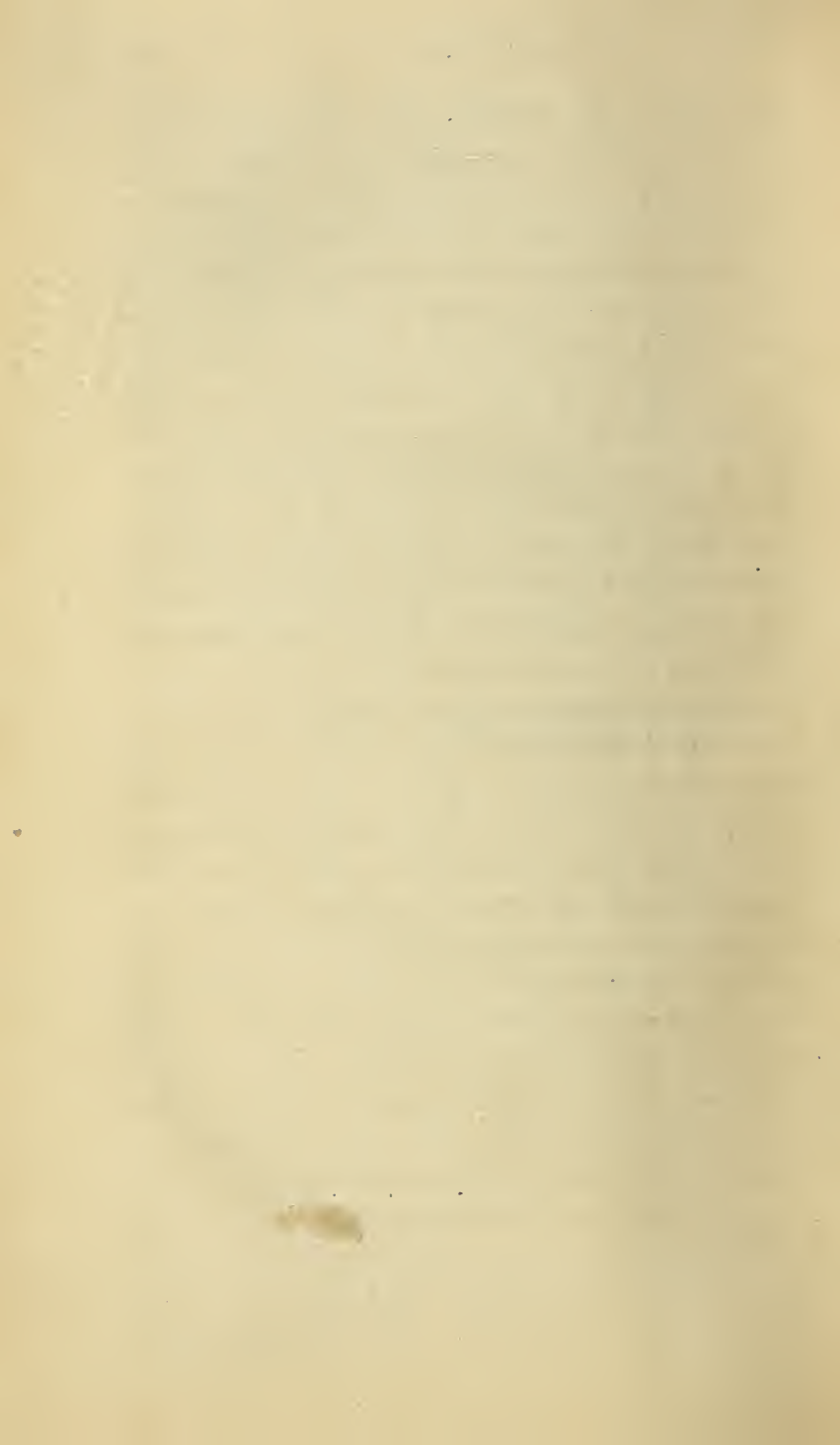
The time has now arrived for his again appearing before the public, and as he has spared no pains to make the following treatise as complete as he possibly could, he trusts it will be favourably received by all classes of readers.

In treating of the Theory of Artificial Light, he has, to a very considerable extent, remodelled his

former plan, and added much new matter, the result of his own practice, as well as of that of others. In treating of the apparatus used in the gas manufactory, he has dwelt very fully upon the leading improvements which have been made in the retorts and modes of setting them, in the condensing (or *refrigerating*) vessels, in the purifier and the gas-holder. On the laying down of main-pipes in the streets, for matter which appears to him *now* redundant, he has added much of a practical nature which he expects will be found useful. He has also noticed the latest improvements in the fitting up of houses and shops, &c., and in the construction of gas-burners. On the governor, regulator, and gas-moderator, he has so fully written as to make the construction and operation of each fully intelligible. He has also dwelt at somewhat more length upon the subject of tests, in order that due precaution may be taken at the manufactory to prevent the possibility of impure gas being supplied to the public. He has almost entirely re-written the chapter on the Chemical Constitution of Coal-gas, and he trusts, thereby, rendered it more valuable. As oil-gas and gas from turf are not likely to be used for illuminating purposes, and as the manufacture of carbonate and muriate of ammonia belongs more properly to the manufacturing chemist than to the gas-light manufacturer, he has but briefly mentioned them. He trusts, however, the

pages taken up in treating upon those subjects in the former editions are employed to better purposes in this, by his furnishing therein a description of the gas-regenerators, and an account of other apparatus, devised for most effectually converting into carburetted-hydrogen gas the tar and ammoniacal liquor produced from the coal in the retort as they, in a state of vapour, are on their passage to the hydraulic main, and by his giving a method for correctly ascertaining the specific gravity of coal or other gases, and also by his explaining in great detail the arrangement of a coal gas-light establishment, as recently erected by him, from a ground-plan, section, and elevations (drawn to a scale).

10, *Arundel Street, Strand, London,*  
22nd March, 1841.



## PRACTICAL TREATISE ON GAS- LIGHTING.

---

### CHAPTER I.

Theory of the Production of Artificial Light, and of the Action of Candles and Lamps; with Directions for ascertaining the comparative illuminating Power of Candles, Lamps, and Gas Lights; and for computing the relative Cost of Light afforded by each.

It is not improbable but this chapter may appear to some readers as redundant, and they may turn away from it with a remark that every one is aware of the theories it treats of; and, therefore, why load a work professedly explanatory of gas apparatus with such matter? Should such remark be made, the reply is simple. The work is intended for all classes of readers who are in any way interested in gas concerns, and few, it is supposed, would be bold enough to affirm that, taking such readers in the gross, all are acquainted with either the theory of artificial light or with that of combustion.

The author of this work is well aware that there are very few books upon any one art or science which can be said to be complete in themselves; authors taking it for granted that readers take them

up with a knowledge of many things of which indeed they literally know nothing. The same thing occurs too frequently at the lecture table, whereas, if the lecturer or the author adopted a different course, both hearers and readers would probably receive more benefit. With such ideas impressed upon the mind, it is intended, in this instance, to begin at the beginning and to proceed step by step to the end, so that when the work is completed it may not, at all events, belie its title-page; and, as it is divided into chapters, those who have no relish for theory can turn to practice, where it is expected they will find matter worthy their perusal.

In treating of the theory of artificial light, if we give the matter due consideration, we cannot fail to perceive that, when usefully employed, it is procured by the agency of fire; and if we follow up our inquiries, we shall find that in all ages of the world, even from the time of our first parents, fire has been known; we shall also find in newly discovered countries that the aboriginal inhabitants were invariably acquainted with that agent. It was directed by the Jewish law that the fire upon the altar should burn continually. In some countries it was considered as the image of life, and hence *lighted* torches were emblematically placed in the hands of the newly married; *extinguished* torches placed upon the tombs of the dead. The fable of Prometheus having stolen fire from heaven furnished (some have

thought) an idea to the early philosophers of its being the soul of the world and the visible symbol of an invisible deity ; as such it has been and is still worshipped by heathen nations.

As to the origin of fire, it is of little consequence to us whether, for ordinary purposes, we procure it by rubbing two dry sticks briskly one against the other, or by the use of flint and steel ; but, we cannot reflect upon the powerful effects of this agent, obtained by other means, without emotions of astonishment and almost reverential awe, being, as it were, simultaneously produced. By a combination of mirrors we can so concentrate the sun's rays as thereby to fuse, almost instantaneously, the most obdurate metal : the mode of arranging such mirrors appears to have been well known in the time of Archimedes ; for, from the walls of Syracuse, it is said, by such means he destroyed the fleet of Marcellus, when acting against that city ; and, notwithstanding this piece of history has frequently been considered as bordering upon the marvellous, the experiments of Father Kircher, and his pupil Schottus, made at Syracuse (*vide Philos. Trans.*, vol. xlviii., page 621), have proved that by a combination of mirrors he might easily have done so.

Fire can be produced by electricity and by galvanism, and it is from the effects of the latter agent that such amazing discoveries have been made in several branches of chemical science. It is also

attainable by compression, by percussion, and by several chemical preparations.

Spontaneous combustion frequently occurs by the decomposition of water, as, for instance, when hay or other vegetable matters are put up in ricks before being properly dried : such also occurs when substances impregnated with oil are laid up in large heaps in a damp state. Peat laid up in very large heaps is subject to the same ; as is also pyritous coal, when piled in the open air, or where water has access to it, the effect of which is sufficient to set fire to the whole mass.

Having now briefly adverted to the mode of procuring fire, and the natural causes by which it is sometimes spontaneously produced, we come next to consider the nature of flame ; and, in doing so, we must set out by observing that such flame as issues from any body submitted to the action of fire, consists of matter which, if collected, would universally possess *hydrogen gas* as one of its component parts. More, if the flame yielded but little light, and less as it increased in brilliancy. Such gas is more or less pure as the matter used for its production is more or less free from impurities : its purity, therefore, and consequent brilliancy, when exhibited as flame, vary with the circumstances under which it was generated. When the circumstances under which the combustion of inflammable matter is carried on are favourable, the flame is perfect and bril-

liant; on the contrary, should the combustion be incomplete, part of the matter capable of furnishing light and heat will pass off in smoke; hence, wherever much soot is found, we may conclude the body producing it had not been used to the greatest advantage.

It seldom happens when coals are used that combustion is carried on advantageously; for to produce a complete combustion, a very small quantity of coals should be supplied to the fire at one time, an arrangement too tedious to be generally adopted. Coals are heaped upon the fire in such a way, that it requires much time to elapse before they are burnt through, and whilst this is going on a dense smoke is continually thrown out which answers no profitable purpose.

The artificial light afforded by an inflammable body, whether it be a candle, lamp, or any other substance, arises from the flame such body may exhibit when in the act of combustion; and as, from what has been premised, it may be concluded that complete combustion is necessary to the economical production of light, therefore the question will be, *how are we to produce the greatest quantity of light at the least expense?*

Perhaps the best rule to be adopted for the purpose would be to allow no more of the inflammable matter to mix with the surrounding atmospheric air than could be consumed. If it be allowed to exhibit

itself in bulky diameters, much of its effect will be lost; for, under such circumstances, the interior of the flame cannot be completely burnt, for want of its being supplied with that due proportion of oxygen which is necessary to produce complete combustion. If the matter submitted to combustion be thrown out at a very low temperature, it will not burn in the open air; it is, therefore, of consequence that the matter for producing flame should have attained a proper heat, and be thrown into the atmosphere with that velocity which will allow it to be wholly decomposed by its burning, so that no smoke may arise from it. If the stream of air acting upon the combustible matter be too great, it will defeat the effect desired; whilst the contrary will so tend to weaken the flame as to render it nearly useless.

The necessity of a proper supply of air for supporting combustion to advantage suggested the idea of the argand lamp, the ingenious inventor of which proceeded upon two principles; the first of which was to increase to the greatest extent the surface of the wick, the second to increase the quantity of air applied to it, and in this way to produce the combustion of all the material absorbed. It is well known that the wick in the argand lamp is thin and circular, and that there are in its wick as many cotton capillary tubes for absorbing the oil as in a common thick wick. By this arrangement the whole of the matter applied, that can be burnt, is consumed

in consequence of the wick being spread through a large surface, and a current of air, produced by the glass chimney, being applied both to the inside and outside of this wick. If the apertures beneath the lamp be stopped, it immediately smokes, in consequence of the heat increasing to such a degree as to distil off the oil more rapidly than the air can effect its combustion ; as soon, however, as the current of air is restored, the combustion becomes again complete and the production of smoke terminates.

Every one who reads or writes much by candle-light must have observed that a small flame is always brighter and more luminous than a large one ; and that when a candle has been newly snuffed it yields from six to eight times the quantity of light which is afforded by it when the wick becomes so lengthened as to make the application of the snuffers again necessary. It is from this variability of the light, as afforded by candles and ordinary lamps, that persons accustomed to read or work long by such lights have their eyes injured ; and this injury is not so much from the light itself as from its fluctuation, which compels the optic nerves to be continually adjusting their action, in order that the eye may be adapted to the light under all its changes.

To remedy the inconvenience arising from the variability of light as just referred to, Mr. EZEKIEL WALKER proposed that tallow candles should be placed in such a direction as to recline thirty degrees

from the perpendicular : for doing this, candlesticks may be easily constructed, or they may be made to hold the candle at any angle which may be desired. When a candle is placed at thirty degrees from the perpendicular, there will be no necessity for snuffing it ; for when it burns thus the flame rises vertically from the upper side of the wick, exposing the top of it, which projects beyond the flame, to the action of the air. By this mode of causing the candle to snuff itself that part of the wick which is acted upon by the flame must necessarily remain of nearly the same length ; and, if the wick is uniformly twisted throughout, the flame will remain of the same strength and dimensions. This can never be effected when candles are snuffed by an instrument ; but when a candle is so placed as to snuff itself, the light is steady, and at the same time so invariable in its intensity, that the eye feels no pain or uneasiness in performing its office.

What Mr. WALKER proposed to effect is spoken of as of a thing probably not universally known ; but the elegant contrivances of Mr. PALMER for burning tallow candles with what he terms metallic wicks answer precisely the same purpose—that is to say, his candles, so to speak, snuff themselves, from the wicks as they untwist themselves spreading out in such a manner that the apex of each projects beyond the body of the flame, is acted upon by the oxygen of the atmosphere and gradually consumed.

His candlesticks are generally elegant in appearance, the light afforded from his candles, *quantum* of light for *quantum* of light, cheaper than from ordinary tallow candles, and the comfort of reading, writing, or working by them greater beyond all comparison.

The improvements in table lamps have within the last few years been great beyond all comprehension. Amongst the best of these are the “*shadowless overflowing lamp*,” and the “*solar-lamp*.” The former, from its producing a constant supply of oil to the wick, will burn with a uniform flame for seven or eight hours without adjustment, so that the light from it is nearly as intense as that produced from gas, quite as regular as to the quantity of light supplied, and not half the expense of common tallow candles light for light. As these are constructed so as to burn common oil, the expense of one which yields as much light as five mould candles of six to the pound, is not so much as it would be for using two such candles in the ordinary way; thus producing a great saving of expense whilst it affords much additional comfort.

The observations just made relative to the improvements of candles and lamps it is to be hoped will not be considered as entirely out of place, as they have for their objects economy and comfort. Our next business will be to observe that it cannot be doubted but bodies which are capable of producing

flame contain such latent matter as supports combustion. Indeed, it is well known that light forms a constituent part of some bodies, for from them it is disengaged as they form new combinations. That the light evolved by artificial means is derived from the matter submitted to combustion is clear to demonstration; for we need but observe the change of colour which flame exhibits during the process of burning to be certified of the fact. Such variation does not depend upon the medium which supports combustion, but is to be solely attributed to the matter of the combustible body. By considering this matter we can easily comprehend the possibility of tinging the colour of the purest kind of flame, by mixing the body producing it with substances for that purpose: thus—

Spirits of wine burn with a bluish flame, and sulphur with nearly the same tinge.

Zinc burns with a bright greenish white flame.

Preparations of copper, or of the substances with which they are mixed, burn with a bright vivid green flame.

Spirits of wine mixed with common salt, when set on fire, burn with a very unpleasant effect.

Spirits of wine and a little boracic acid, or nitrate of copper, stirred together and set fire to, burn with a beautiful green flame.

Spirits of wine mixed with nitrate of strontia, burn with a carmine red colour.

Muriate of lime tinges the flame of burning spirits of wine of an orange colour.

As for the colours of flame exhibited when coals, wood, and other combustibles are used, their different shades amount but to a few of red, purple, and yellow. These, doubtless, arise from the greater or lesser quantity of watery vapour, or smoke, which passes through the flame unburnt, with the other incombustible products.

By observing the flame of a common candle carefully, we shall perceive that the colour of it is not uniformly alike; the lower part next to the cup formed in the tallow is always blue, the part contiguous to the wick is opake; the exterior to the height of the wick bright and luminous, as it is also to the top of the flame immediately after the candle is snuffed; but, when the flame becomes lengthened and the top of the wick assumes a fungus-like appearance, the apex of the flame will then be of a reddish or brownish colour.

In proceeding to illustrate the theory of the action of candles, lamps, &c., we are to observe that whenever light is to be procured, for ordinary purposes, the most ready means of obtaining it is by the process of combustion. The most common method of obtaining artificial light, where the use of candles and lamps is unknown, is, by burning masses of wood or other matter in their solid state; but where improvements have gained footing, artificial light has

for most purposes, till within the last thirty-five years, been obtained by the means of lamps and candles. About the period just alluded to, public attention was called to Gas, procured from coal, as a substitute for candles and lamps, as being a much cheaper and far more effective mode of procuring light; and, although the progress made in that great improvement was but slow in the beginning, the almost universal adoption of Gas for street and shop lighting since, points out to us that it has perhaps spread its usefulness throughout the British Empire as well as upon the continents of Europe and America, with equal if not greater rapidity than has fallen to the lot of any modern improvement.

When lamps are used, it is necessary that the combustible material should be such as will remain in a fluid state at the usual temperature of the atmosphere. In the use of candles the case is different, for the matter of which they are formed does not become fluid but by a very considerable application of heat. Of whatever substance, however, the instrument for yielding light is composed, it is required to be rendered volatile before flame can be produced; and, for this purpose it is not necessary to volatilize much of the matter at a time, as a very small portion of it will be sufficient for affording a useful light. A candle or lamp contains sufficient combustible matter to last several hours; and it is by the operation of the wick that the operation of generat-

ing light is effected. In using a lamp, the oil should be such as will readily inflame, and the wick of sufficient capacity to convey to the place of combustion, by capillary attraction, such quantity of oil as by admixture with the oxygen of the air, will be completely consumed. By this attraction, the oil continually flows to the laboratory, where the decomposing process is carried on.

On a candle being first lighted, such a degree of heat is given to the wick as is sufficient to melt the tallow, which is formed into a kind of cup where it is decomposed. It is in this part that the carburetted hydrogen gas and vapour are mixed with the air, and yield a bluish flame. This, however, communicates so much heat to the higher part of the gas evolved as to give it a yellowish tinge. As the tallow melts, and becomes decomposed by the action of the wick, a fresh supply continues to be given. The upper part of the wick, which is surrounded by the flame, becomes black, owing to part of the carbon and hydrogen produced by combustion entering into its composition, the wick being defended from the action of the air by the flame which surrounds it. There cannot be a doubt but to this circumstance the wick owes its protection; for, when by the consumption of the tallow the wick becomes too long to support itself vertically, the top projects beyond the flame (which will invariably be the case when

the wick deviates from a perpendicular line), and being thus exposed to the action of the air, burns off and is soon converted to ashes.

As part of the tallow which is volatilized is not burnt, owing to its passing through the centre of the flame, and not being acted upon by the oxygen of the surrounding air, it passes off in smoke; hence it follows, when the wick and flame are large, there is proportionably greater waste of combustible material than when the wick and flame are small. Indeed, when a candle is made with a wick of a single thread, though it yields but a very small flame, yet such flame is not only particularly bright but free from smoke, whilst, on the contrary, in common lamps, where a very large wick is used, the smoke is considerable, and tends to lessen the strength of light which, from the quantity of matter used, might naturally be expected.

As in the process of combustion of candles the fluid tallow is contained in the cup formed at their top, it follows that the thickness of the wick is a circumstance requiring attention; for, if the wick be not of sufficient capacity for carrying off the fused material as rapidly as it enters into a state of fusion, it will run down the sides of the candles; or, as we familiarly express it, "the candle gutters." This inconvenience, arising from the nature of the material of which the candle is formed, it appears, that

as wax is not so fusible as tallow, the wick of the latter description of candle may be made much slighter than the wick of the former.

A candle with a thick wick, when first lighted and snuffed short, yields a flame perfect and luminous, unless the diameter of the wick be very great; in such case the middle of the flame will be opaque, as for want of a proper supply of oxygen the combustion cannot be completely effected. But when the wick becomes lengthened, the distance between its top and the top of the flame given out will be shortened; and the tallow which is decomposed, having a shorter distance of flame to pass through, is not entirely burnt, and that part which is not so passes off in smoke. The wick, if not snuffed, continues to lengthen till, unable to support the accumulation of soot formed round the top of it, it falls on one side, allowing the air to act upon it; or, otherwise, the upper part of the flame given out is so shortened as to expose the top of the wick to the air; in the latter case, however, spontaneous snuffing is not effected. The portion of the tallow carried off by the lengthened wick is too great to be entirely burnt, and it takes off a considerable portion of the heat of the flame as it assumes a state of elasticity. This process tends to diminish combustion, whilst a greater supply of tallow, in a fluid state, produces an accumulation of soot at the top of the wick; and, when much soot has been there deposited, the

candle does not give more than from a sixth to an eighth of the light which the materials submitted to combustion, if properly managed, would produce : it is from this circumstance that ordinary tallow candles so frequently require snuffing.

When wax candles are used, it is found that as the wick lengthens the intensity of light decreases ; but then, as the wick is very thin in comparison with the wick of a tallow candle, it sooner falls from the middle of the flame, and, the top becoming exposed to the air, is burnt off. When the wick of a wax candle is in the centre of the flame, it is not of sufficient magnitude to cause the diameter of that flame to be so enlarged as to prevent the air having access to it. It follows, from what has been said, that as wax is with difficulty fused, a large quantity of it may be burnt by means of a very small wick. It is from this circumstance the wick, of course, is pliant, and soon becomes unable to support itself in a vertical position ; on its losing that position, the action of snuffing is spontaneously performed in the manner already noticed, and with much greater precision than it could have been by any mechanical operation.

If we take into consideration what has been said relative to wax and tallow candles, it will appear that the making of the latter so as to be equal to the former cannot be effected, unless by some contrivance we can render tallow as difficult of fusion as wax ;

for the advantage which a wax candle has over one of tallow arises from wax requiring a higher temperature to fuse it, consequently the fusion is not so rapid and the cup formed by the action of the flame not so soon destroyed. Therefore, to render tallow when used for generating light equal to wax, it must either be burnt in a lamp, or to prevent the melted material running to waste, the wick must be made of a more pliant material than is at present used, or the tallow itself must, by some chemical arrangement, be rendered less fusible.

When we are desirous of ascertaining the illuminating power of candles or other luminous substances, we must have recourse to some method different from that of simply viewing the lights themselves, and by the eye forming a comparison between one light and another; the organs of human vision are not adapted to ascertain with sufficient accuracy the exact proportion which one light may bear to another placed near it, by first looking at one light and then at the other. But, though from such examination of different lights their intensities cannot be ascertained accurately, yet the eye is peculiarly adapted for judging of the strength of shadows; so much so, that by proper arrangements the proportional quantities of light, emitted by two or more candles, lamps, or gas-lights, may be determined with almost mathematical correctness, and the comparative strength of light afforded by a gas-burner

compared with what is given out by one or more candles of certain dimensions.

Light always travels in straight lines, and in every direction from the body yielding it, therefore its strength must decrease in proportion to the distance from the point of divergency. Therefore, by supposing two or more lights to be placed at such distances from an interposing opaque object, as to cause shadows of equal intensity to be cast upon something white fixed to a wall behind it, if we measure the distance of each light from its respective shadow, we obtain data for ascertaining the proportionate illuminating power of each; for whatever light falls upon any body would have fallen upon the place occupied by its shadow had there been no interposing object; and this position may be established in the following manner:—

Let the light (suppose of a candle) which flows from a point A, plate I, fig. 1, and passes through a square hole, B, be received upon a plane, C, parallel to the plane of the hole; or let the figure C be the shadow of the plane B, and when the distance C is double of B, the length and breadth of the shadow C will be each double the length and breadth of the plane B, and treble when A D is treble of A B and so on, which may easily be examined by the light of a candle placed at A. Therefore, the surface of the shadow C, at the distance A C, double of A B is divisible into four squares, each equal in area to the

Fig. 1.

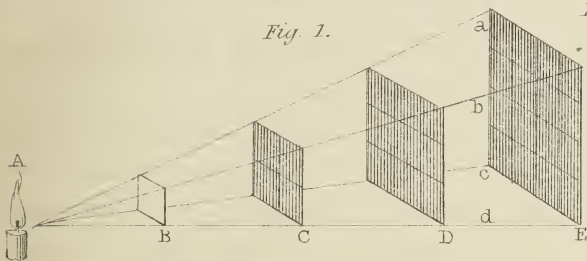


Fig. 2.

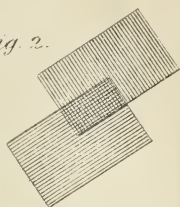


Fig. 3.

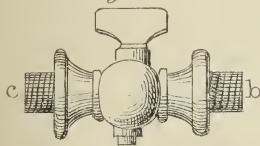


Fig. 4.

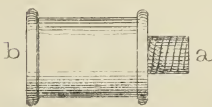


Fig. 4\*

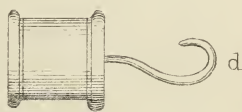


Fig. 5.

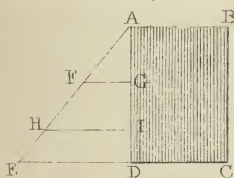


Fig. 6.



Fig. 7.

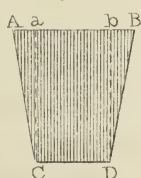


Fig. 8.

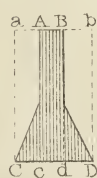


Fig. 9.

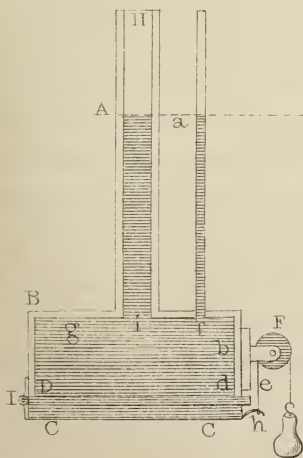
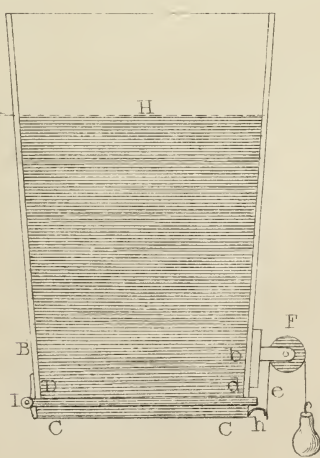


Fig. 10.



Tho<sup>s</sup> S. Peckston:

London, Published by E. Herbert 20<sup>th</sup> Feb<sup>y</sup> 1841

C. Burton del<sup>t</sup>



square *B*, at a treble distance into nine squares, each equal to the square *B*, as represented in the figure. The light, then, which falls upon the plane *B*, being suffered to pass to double that distance, will be uniformly spread over four times the surface, and consequently will be four times fainter in every part of that space; at a treble distance it will be nine times fainter, and at a quadruple distance sixteen times fainter than at *B*, and so on, according to the increase of the square surfaces *B*, *C*, *D*, *E*, built upon the distances *A B*, *A C*, *A D*, *A E*. Consequently, the quantities of this rarefied light, received upon a surface of any given size and shape whatever, removed successively to these several distances, will be but one-fourth, one-ninth, one-sixteenth of the whole quantity received by it at the first distance, *A B*; or, in other words, the densities and quantities of light received upon any plane are diminished in the same proportion as the squares of the distances of that plane from the luminous body are increased; and, on the contrary, are increased in the same proportion as these squares are diminished.

From what has been said, it follows, that as the shadow of any body, at twice the distance of the surface from the point of illumination, will occupy a space four times the area of the interposing object, consequently the strength of light will decrease as the square of the distance is increased. Therefore, by placing two lights in such situations as to throw

shadows of equal densities upon a white wall or screen, from some opaque substance placed between them and that wall or screen, the intensity of light afforded by each will be inversely as the squares of their distances from the shadows. When two lights of unequal illuminating powers are so placed as to produce shadows contiguous to each other, from an opaque interposing body, the stronger light will yield the deepest shadow, and the weaker light the faintest shadow. In making experiments for ascertaining the intensity of different illuminating bodies, it is necessary that they should be so placed as to produce shadows contiguous to and partly impinging upon each other, and of equal intensity.

When it is required to compare the intensities of light produced by candles of different sizes, the following mode may be adopted. Fix a sheet of paper against the wall of your room at a convenient height, and place a small fire screen at a few feet distant from it, taking care to fix the part intended to throw a shadow upon the paper, at a proper height for doing so. Then let one of your assistants take the candle which yields the smallest quantity of light, and proceed to such a distance from the screen as may be convenient, but so as to allow the shadow to be produced to fall upon the paper. Next, let him who holds the candle yielding the strongest light proceed in nearly the same direction from the screen as the former, till the shadow from his candle falls

nearly upon the same part of the paper as that produced by the weakest light. Should the darkness of shadow from the strongest light be greater than that produced by the weaker, let your second assistant increase his distance from the interposing object till the shadow from each candle is equally dark ; this being done, measure the distance of each light from the paper receiving their respective shadows ; then say,

As the square of the distance of the weakest light  
from the shadow,

Is to the square of the distance of the strongest  
light from the shadow,

So is unity, (or 1)

To a fourth number, and that number shows the  
proportion of light yielded by the strongest light  
as compared with that yielded by the weakest one.

The same result will be produced by dividing the square of the distance of the strongest light from the shadow by the square of the distance of the weakest light therefrom.

But, by way of example, let us suppose we have proceeded agreeably to the plan already pointed out, with two candles of different illuminating powers, and have measured the distances of each from the shadows, and found the weaker light to be at six feet distance from the shadows, and the stronger light at twelve feet ; and desire to know how many candles of the least illuminating power, if placed

close together and in the same situation, as to distance from the interposing object as the stronger light, would produce a shadow equally strong, and consequently the same quantity of light.

The square of 6 is equal to 36

„ „ 12 „ 144

therefore, as  $36 : 144 :: 1 : 4$  or  $144 \div 36 = 4$ , the number of candles of the smaller illuminating power which would be required to be all lighted at one time, and placed close to each other, to produce the same intensity of light as the larger candle.

This method may be adopted whenever the illuminating bodies are such as can be moved; cases, however, occur sometimes which render a trifling deviation therefrom needful. For instance, when one of the bodies emitting light is stationary, as in the case of a gas-burner. Then in making the experiment it will require but one candle to be used, which must be moved backwards and forwards between the interposing body and the burner, till the shadows from each upon the paper against the wall are equally dark. To judge accurately of the strength of each shadow, the candle should be held in such a position as will allow the shadows from it and from the gas-burner to be shown upon the paper contiguous to, or rather impinging upon each other. (See plate I. fig. 2.) Measure the distances from the gas-burner, and from the candle to the shadow, and then proceed as already directed; the

following example will more fully explain the matter:—Having adjusted the flame of a gas-burner to two inches in height, and placed an opaque body between it and a sheet of white paper attached to a wall twelve feet distant from the burner, a mould candle of six to the pound was introduced between the burner and the body producing the shadow, and moved backwards and forwards till the shadows produced by the gas-burner and the candle were equally dark; on their being so, the candle was found by admeasurement to be four nine-tenths feet from the shadow produced; the number of such candles to produce as much light as is given by the burner, are required,

$$\text{The square of } 4 \cdot 9 = 24 \cdot 01$$

$$\text{,, ,, } 12 \cdot 0 = 144 \cdot 00$$

Then as  $24 \cdot 01 : 144 :: 1 : 6$ , or  $144 \div 24 \cdot 01 = 6$  nearly, the number of candles necessary to produce the same intensity of light as is afforded by the gas-burner.

From experiments made in this way, without the aid of any description of photometer, although the more scientific reader may prefer the use of such description of instrument as that invented by Professor Leslie, it may be determined, whether more or less light is obtained by burning several small candles, or one or more of greater dimensions, during a given time, at the same expense; for, by such, the intensity of light afforded by each is ascertained: and, the quan-

tity of matter consumed for obtaining it is easily ascertainable. The same thing holds good with respect to lamps and gas-burners, and nothing is more easy than to compare the illuminating power of each, and to ascertain the relative cost of any substance which may be employed for furnishing light.

As by turning the stop-cock which supplies a gas-burner, the light afforded by it can be adjusted to that of a well-snuffed tallow candle; if then the experiment be carried on for some specific time, and the candle be weighed before the experiment is commenced, and again immediately after it is ended, (the price per pound of candles being known,) the person making the experiment will ascertain the cost of procuring light by such candle for the said time. The quantity of gas consumed by the burner, as pointed out by the index to the experimental gas-holder, or gas-meter, will enable him to ascertain the cost of procuring a similar light by the use of gas. To enable him to do this he must, however, inform himself at what cost a specific number of cubic feet of gas can be generated.

Although what has been just stated holds perfectly good when the comparison is made between a single jet gas-burner when adjusted so as to emit the same quantity of light as a tallow candle of six to the pound, and which in that case would consume about seven-tenths of a cubic foot of gas per hour, it by no means shows the saving effected by the use

of gas when burners of a larger size are used. It is very well known that supposing we use candles for obtaining the light we require, should we not find one sufficient, if we lighted two it must be at twice the expense, if three at thrice the expense, and so on. The case is similar with oil lamps, at all events to a considerable extent; but with gas the case is altogether different. No one would think, who uses gas now, of putting five or six single jet lights (unless for some specific purpose as to situation) for obtaining five or six times the quantity of light; he would see that such mode would be very injudicious and anything but economical. He would argue thus from what in all probability he had heard from his neighbours, or from his own observations, as to the effects produced by gas-burners of different sizes. The burners affording the greatest quantity of light from the least quantity of gas are the argands of  $\frac{1}{16}$  of an inch diameter with twelve holes, and of  $\frac{1}{16}$  of an inch diameter having fifteen holes; in each size the holes are  $\frac{1}{32}$  of an inch in diameter. A burner of this description, consuming five cubic feet of gas per hour, gives as much light as twelve mould candles of six to the pound. Now, as it was remarked before that a single jet light adjusted so as to be equal to one such candle, consumed  $\frac{7}{10}$  of a cubic foot of gas per hour, it follows of consequence that twelve such lights would consume  $\frac{7}{10} \times 12 = 8.4$  cubic feet of gas, whereas one

argand burner, consuming but five cubic feet per hour, would afford as much light. A saving, therefore, arises to the consumer of 3·4 feet per hour by using one argand instead of twelve single jet burners.

It was long since determined, from experiments made by Count Rumford for ascertaining the quantity of materials necessary to produce a light of a certain intensity, for a given time, that there must be burnt by weight :

Of wax 100 pounds, of tallow\* 101 pounds, of oil in an argand lamp 129 pounds, and of an ill-snuffed tallow candle 229 pounds; and from an immense number of experiments made upon coal gas by various persons, at different places, and under a variety of circumstances, we may reckon that to procure as much light as is afforded by 100 pounds of wax candles 5,500 cubic feet of coal gas (at an average) would require to be consumed. If we take the present price of wax, tallow, oil, and coal gas, (at the price charged in London,) we shall find that the comparative cost of the different modes of lighting will stand thus:—

	£.	s.	d.
72½ lbs. of wax candles, at 2s. 6d.			
per lb. - - - - -	9	1	3
101 lbs. of best Kensington mould			
candles, at 8d. per lb. - -	3	7	4

\* 72½ lbs. of wax candles will burn as long as 100 lbs. of tallow candles of the same size and number to the pound.

	£.	s.	d.
129 lbs. of oil (spermaceti), at 1s.			
per lb., or 9s. per gallon -	6	9	0
229 lbs. of ill-snuffed tallow candles			
(dips), at $6\frac{1}{2}d.$ per lb. -	6	4	$0\frac{1}{2}$
5,500 cubic feet of coal gas, at 9s. per			
thousand cubic feet -	2	9	6

In pursuing our inquiries relative to the comparative cost of obtaining light from materials of different description, we shall find we are indebted to Mr. Ezekiel Walker for some valuable matter communicated to the public through the medium of the 8vo. series of Nicholson's Journal, from which the following is extracted:—"A mould candle of six to the pound, in two instances, consumed 15 drams in three hours; in a third instance, 1 ounce in three hours; and in a fourth,  $17\frac{1}{8}$  drams; so that, taking the average, one pound of such candles would last about fifty hours, or equal to fifty such candles, each burning an hour, cost, as above, 8*d.*"

An imperial gallon of sperm oil burnt in an argand lamp which yields light equal to five candles, will burn somewhere about 100 hours, or equal to 500 candles, each burning one hour; the expense per hour, when sperm oil is 9s. per gallon, will be a little more than a penny for such lamp; but when whale or seed oil, which are now very much used in the late invented "overflowing shadowless lamp," and also in the "solar lamp," supply the place of

sperm oil, as these oils can be purchased at from 3s. to 3s. 6d. per gallon, we find that an imperial gallon will burn about ninety hours, and furnish light equal to  $4\frac{3}{4}$  mould candles of six to the pound, or equal to  $427\frac{1}{2}$  candles, each burning one hour. These lamps, with whale or seed oil, will cost not quite one halfpenny per hour.

It is generally admitted that an argand burner of fifteen holes will consume about five cubic feet of gas per hour, and yield a light equal to twelve mould candles of six to the pound.

Hence we may put the comparative cost of different modes of procuring light in a somewhat different shape to what has been already done, thus:—

	£.	s.	d.
A quantity of light equal to that produced by 500 candles of six to the pound, if obtained from wax candles, at 2s. 6d. per lb., will require $7\frac{1}{4}$ lbs., and cost - - - -	0	18	$1\frac{1}{2}$
An equal quantity of light, when obtained from sperm oil, costs - - -	0	9	0
An equal quantity of light from 10 lbs. of short six tallow candles, costs - - - - -	0	6	8
An equal quantity of light from whale or seed oil costs - - - - -	0	4	3
An equal quantity of light from 210 cubic feet of coal gas costs - - -	0	1	$9\frac{3}{4}$

£. s. d.

And if an equal quantity of light were  
to be procured by the use of ill-  
snuffed dip candles, it would hardly  
be obtained for less than the price  
given for sperm oil, that is to say - 0 9 0

We may, however, perhaps put the above in a still  
plainer point of comparison by making the cost of  
wax candles the standard, and subsequently letting  
the others follow, decimally expressed, thus:—

Wax candles - - - - - 1·000

Sperm oil burnt in argand lamps - - - ·496

Ill-snuffed tallow candles - - - ·496

Tallow candles (mould) six to the pound - ·368

Whale or seed oil, burnt in the “over-  
flowing shadowless lamp,” or the  
“solar lamp” - - - - - ·234

Coal gas - - - - - ·100

Or, if the cost of wax candles be 1s., the cost of  
these other means of equal illumination will be as  
under:—

£. s. d.

Wax - - - - - 0 1 0

Sperm oil - - - - - 0 0 6

Ill-snuffed tallow candles - - 0 0 6

Tallow candles - - - - - 0 0  $4\frac{1}{2}$

Whale or seed oil - - - - - 0 0  $2\frac{3}{4}$

Coal gas - - - - - nearly 0 0  $1\frac{1}{4}$

The experiments which have been made for the

purpose of coming at the above results give evidence that the quantities of light produced by tallow candles are in such proportion to each other as would be expressed by multiplying the time that the candle is burnt by the quantity of matter consumed. This law being established, we have a standard given by which we may compare the strength of various lights; for, if a small mould candle be lighted, and so placed as neither to produce smoke nor require snuffing, it will lose in weight a little over five drams in an hour, or about one ounce in three hours. The quantity of light so produced may be expressed by 1; should it, however, at any other time lose more or less weight in three hours than an ounce, the quantity of light it yields may be ascertained, for the quantity of light produced in a given time (the combustion being perfect) is always in a direct proportion to the quantity of matter consumed.

From what has been said on the subject arise the two following theorems:—

First. When the quantities of matter of two or more bodies consumed are equal, and times of burning the same, they will give equal quantities of light.

Second. When the times of burning of two or more bodies are equal, the quantities of light emitted by each will be in direct proportion to the respective weights of matter consumed.

Corollary. It follows, as has been before observed,

that the light produced by any number of bodies used for the purpose of generating it, is always in the compound ratio of the time of burning and weight of material burnt.

Hence we are able to lay down the following rules for investigating such subjects:—

Let *M* represent the mould candle;

*d* its distance from the wall on which the shadows were compared;

*m* its quantity of matter consumed in a given time;

*t* express that time; and

*Q* the quantity of light emitted by *M* in the same time.

Let *C* represent any other candle;

*δ* its distance from the wall;

*q* its quantity of matter consumed in a given time;

*τ* that time; and

*g* the quantity of light emitted by *C* in the same time.

The intensity of light being directly as the squares of the distances of the two candles from the wall, we have—

As  $d^2 : \delta^2 :: Q : g$ , the quantity of light emitted by *C* in the same time as that emitted by *M*.

Then, supposing the quantities of light to be in direct proportion to the quantities of matter consumed in the time *t*, we have—

As  $m : q :: Q : g$ , the quantity of light emitted by C in that time.

Therefore  $\frac{\delta^2 \times Q}{d^2} = \frac{q \times Q}{m}$  and the quantities of light of M and C are in proportion to the quantities of matter consumed by each in any specific time. To make this matter quite easy to every reader, the two following rules are subjoined for solving questions of this description.

**PROPOSITION 1st.**—Given the distance of one candle from the wall where the strength of shadow is observed, the quantity of light emitted by the same in a given time, and the distance of another candle or other luminous body throwing a similar shadow upon the same wall from it; to find the quantity of light which will be produced by the latter in the same time as the former.

**RULE.**—As the square of the first candle's distance from the wall is to the square of the second candle's (or other luminous body's) distance from the said wall, so is the quantity of light emitted by the first candle to the quantity of light emitted by the second in the same time.

**PROPOSITION 2nd.**—The weight of one candle consumed in a given time, the quantity of light emitted by the same, and the weight of another candle consumed in a like time being given (the candles being so placed as to throw shadows of equal intensity upon the same wall); to find the quantity of light

which will be produced by the latter in the same time as the former.

**RULE.**—As the quantity of matter consumed by one candle in a given time is to the quantity of matter consumed by the other in a like time, so is the quantity of light emitted by the first candle to the quantity of light which is emitted by the second.

These rules may be followed for comparing the strength of the light of candles of different sizes with each other, and for ascertaining their relative cost. They are, by transposition, capable of producing various statings, and are easily applied to practice.

The rules, &c. relative to ascertaining the quantity and cost of light procured from luminous bodies, and for comparing the expense at which a given quantity of light may be procured by divers methods, to some may appear of little use; but it may be observed to such, that the author considers he is writing for practical men as well as for men of science. From upwards of twenty years' experience in the lighting of towns with gas, he is enabled to state that without such rules many a practical engineer (perhaps possessing no other work which treats upon the same subject) who might be called upon to light a town with gas, where such light had not been before used, would find considerable difficulties arise to prevent his making his arrangements advantageously; and which a judi-

cious application of the matter given in this chapter, relative to comparing one description of light with another, will tend to prevent.

It may not be uninteresting to some readers to know that a taper lamp fitted with a wick of eight threads of cotton will consume in one hour 0·50775 ounces of spermaceti oil, and that such a lamp yields about  $\frac{7}{8}$  the quantity of light as a mould candle of six to the pound. It requires snuffing but seldom, and casts a steady and strong light, and, when oil is sold at 9s. per gallon, the expense of burning it twelve hours is rather more than  $5\frac{1}{4}d.$

A chamber lamp, with a wick of four ordinary threads of cotton, consumes in an hour 0·22283 ounces of spermaceti oil, and, when oil is sold at 9s. per gallon, it can be kept burning for twelve hours at an expense of  $2\frac{1}{4}d.$  nearly.

One pint and a quarter of whale oil, when used for the purpose of generating light by means of a lamp, is found to be equal in illuminating power to a pound of tallow candles, eight to the pound, set up and burnt out one after the other.

The suggestions of Dr. Franklin relative to a greater proportion of light being obtained by using two candles in such a position as allows the flames to touch each other than when they are burnt separately, has been proved by many experiments to extend to the flames of gas-lights; for these when combined yield a much stronger light than they

would afford if used in a separate state; and whenever flames are placed near to each other, the illuminating consequences are always most beneficial, inasmuch as thereby the heat of the respective flames are preserved, for they act in mutual defence against the cooling influence of the surrounding air.

As the argand lamp, from whence the idea of the argand burner was evidently taken, is superior in its effect, and at the same time more economical than any other; so also great advantages arise from burning gas upon a similar principle; for by the use of the argand burner the junction of many flames is effected without any fear of the light being deteriorated from its not being exhibited in a thin surface. If we reflect that flame is transparent, there cannot arise an apprehension of the strength of light afforded by a burner or a lamp (in which the flame is exhibited between two concentric circles), where the outer surface is the surface of a cylinder, being diminished on account of one part of the flame being covered by the other.

We have endeavoured to explain the modes by which a comparison as to intensity between one light and another may be made, and also how the cost of each may be ascertained; and have also stated the cost of a given quantity of light obtained from wax and tallow candles, from spermaceti and other oils, and from coal gas, in order that our readers may have those things brought immediately before their

notice; and as we expect gas consumers will be benefited by one or two remarks resulting from long experience relative to the most economical mode of using gas, we propose with such, and a table of comparative costs of obtaining light, to bring this chapter to a conclusion.

It will be seen from what has been already said that small burners, such for instance as single jets, are not so economical as large ones; for by the former it would require about  $8\frac{1}{2}$  cubic feet of gas to obtain the same quantity of light as would be afforded from 5 cubic feet consumed by means of an argand burner. It may, therefore, be taken for granted that the twelve and fifteen-hole argand burners are the most economical; and, of the two, the fifteen-hole burner, quantum of light for quantum of light, is superior to the twelve. In using argand burners, however, the consumer should always do so with chimney glasses, and be careful that the flame should never on any account rise higher than from 3 inches to  $3\frac{1}{2}$  inches. If it be allowed to rise higher more gas will find its way through the burner than can be consumed, and consequently a portion of it will pass off in smoke to the injury of his ceilings or goods, or both.

COMPARATIVE STATEMENT of the Illuminating Power, and Expense per Annum, of Gas, Candles, and Spermaceti Oil.

Description of Burners.	Gas Light.		Equal to		Consumption for One Year, from Sunset till Eleven o'Clock.			Annual Expense of Light from Sunset till Eleven o'Clock.					
	Height of Flame.	Consumption per hour.	Tallow or Wax Candles		Argand Oil Lamps.	Gas.	Tallow Candles.	Wax Candles.	Sperm Oil.	Gas, at 9s. per 1000.	Tallow Candles, at 8d. per lb.	Wax Candles, at 2s. 6d. per lb.	Sperm Oil at 9s. per gallon.
			No.	No.									
Single jet . . . . .	In.	Feet.	No.	No.		Feet.	lbs.	lbs.	Gals.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Ditto . . . . .	2	$\frac{1}{2}$	1	..		920	40	29	..	0 8 3 $\frac{1}{4}$	1 6 8	3 12 6	..
Two jets, flames conjoining.	4	$\frac{6}{10}$	2	..		1,640	80	58	..	0 14 9	2 13 4	7 5 0	..
Three jets . . . . .	5	3	4	1		3,630	160	116	17 $\frac{1}{2}$	1 12 10	5 6 8	14 10 0	0
Twelve-hole argand. . . . .	4	3	4	1		5,480	160	116	17 $\frac{1}{2}$	2 9 4	5 6 8	14 10 0	0
Ditto . . . . .	3	3 $\frac{1}{2}$	5	1 $\frac{3}{4}$		5,940	200	145	30 $\frac{3}{4}$	2 13 5 $\frac{1}{2}$	6 13 4	18 2 6	6
Fifteen-hole argand. . . . .	3 $\frac{1}{2}$	3 $\frac{1}{2}$	7	1 $\frac{3}{4}$		6,400	280	203	31 $\frac{1}{2}$	2 17 7	9 6 8	25 5 6	6
	3	5	12	2		9,130	480	348	35	4 2 2	16 0 0	43 10 0	0

The above Table is calculated on the supposition that the Gas, the Candles, &c., are burnt in exactly similar circumstances; where the positions are varied, the expense will in like manner differ from what is here given, much of the economy of Gas light depending on a judicious arrangement of the burners, and the proper height of the flame.

The consumption being given in the above Table for one year (of 365 days) of Gas per burners, as therein specified, also of Tallow Candles, Wax Candles, and Sperm Oil; the comparison can be carried out at any other cost of the materials named.

## CHAPTER II.

On the Natural History of Pit-Coal, and its component Parts, as ascertained by Analysis: also accounts of the quantities of Gas generally obtained by the Manufacturer from Coals of different Species.

COAL, or *pit-coal*, as it is called in mineralogy, is a solid inflammable substance, somewhat shining, dry, and light, compared with the strata in which it is found. In this country it is very abundant, and may be considered almost inexhaustible. It is peculiarly adapted for domestic purposes, as well as various uses in the arts. It is found chiefly in the countries lying nearly in the same latitude as Great Britain. It is likewise said to be found in the northern parts of China. In the southern hemisphere it is stated to be very abundant in New Holland; but we have no distinct account of coal in the continent of Africa. Of this substance there are several species.

1st. *Jet*. This substance is found in France, Spain, Germany, Great Britain, and other countries, in detached kidney form masses of various sizes, from one inch to seven or eight feet in length. The colour is a deep black; internal, glossy opaque; not so brittle as asphaltum; texture striated; fracture conchoidal; specific gravity 1.259. It has no smell,

except when heated, and then it resembles asphaltum in its odour. It melts in a strong heat, burns with a greenish flame, and leaves an earthy residuum. It becomes electric by friction, and when distilled yields a peculiar acid.

2nd. Cannel coal. This is found in Lancashire and in different parts of Scotland. It is of a bright black colour; opaque; structure sometimes slaty; texture compact; it breaks easily in all directions, and, if broken transversely, presents a smooth conchoidal surface.

It burns with a lively flame, like a candle, as perhaps its name implies, but is very apt in burning to throw splinters to a great distance; it is said, however, to be deprived of this property by being immersed in water for some hours previous to being used. In the coal-field at Wigan, there is a stratum of this coal, unmixed, nearly four feet in thickness. Cannel coal is susceptible of polish, and, like jet, is often wrought into trinkets.

A specimen of Lancashire cannel coal, analyzed by Mr. Kirwan, contained 75·20 charcoal, 21·68 maltha, and 3·10 alumina and silica, or together 99·98. A specimen of the slaty kind, from Ayrshire, called splent coal, was composed of 47·62 charcoal, 32·52 maltha, and 20·00 earths, or together 100·14. The specific gravity of cannel coal is from 1·282 to 1·426. This coal does not soil or stain the fingers when handled.

3rd. Common coal. This very useful combustible is never found in the primitive mountains, but only in the secondary mountains, or in plains formed of the same materials with them. It is always in strata, and generally alternates with clay, sandstone, or limestone. The colour is black, more or less perfect; lustre usually greasy or metallic; opaque; structure generally slaty; specific gravity 1.25 to 1.37; usually stains the fingers, takes fire more slowly, and burns longer than cannel coal; cakes more or less during combustion. Of this species there are many varieties in Great Britain, distinguished by the names of caking coal, rock coal, &c. Mr. Kirwan analyzed a variety of different kinds of coal of this species. The results of some of his experiments are exhibited in the following table:—

Whitehaven.	Newcastle.	Wigan.	Swansea.	Leitrim.	
57.	58	61.73	73.53	71.43	Charcoal. Maltha and Asphalt. Earths.
41.3	40	36.7	23.14	23.37	
1.7	2*	1.57	3.33	5.20	
100.0	100	100.00	100.00	100.00	

4th. Spurious coal. This species is generally found amidst strata of genuine coal: it is also called parrot-coal in Scotland. The colour is greyish black; structure usually slaty; texture earthy; specific gravity 1.5 to 1.6; generally explodes and bursts when heated. It is composed of charcoal, maltha, and asphalt, and above 20 per cent. of stony matter.

\* Earth and metallic matter and sulphur.

5th. Anthracite. This substance, as we are informed by Dolomieu, is found exclusively in the primitive mountains. It is commonly amorphous; sometimes crystallized in short hexagonal prisms; colour black or brownish black; structure slaty; fragments rhomboidal; specific gravity 1·3; often stains the fingers. This species burns precisely like the spurious coal, leaving 40 per cent. of white ashes. According to Dolomieu it is composed of about 64·0 charcoal, 32·5 silica, and 3·5 iron, or together 100·0.

6th. Kilkenny coal. This mineral has been found in Hungary, Italy, France, Ireland, and Wales. It occurs in stratified masses, or in lumps nested in clay; the colour is black; opaque; texture foliated; specific gravity 1·4 to 1·526; often stains the fingers; insoluble in acids; deflagrates with nitre; does not burn till wholly ignited, and then consumes slowly without emitting flame or smoke. It consists almost entirely of charcoal and sulphur; the latter is in a very large proportion, which sends out while burning a suffocating effluvia. It does not produce any soot, but whitens the places where the fumes are condensed.

7th. Culm coal. This species of coal has nearly the same appearance as that of common coal, but its texture is more dull. In Sweden it is considered a distinct species; but what is commonly denominated culm in England is the refuse or dust produced by working the different kinds of coal. It is difficult to kindle except in furnaces where there is a great draught of air.

8th. Sulphureous coal. This is a dull and heavy species of coal; it contains a very considerable portion of pyrites, and produces a great quantity of ashes. There is a great danger attends the working of this coal; for, if any considerable quantity is left together, it generates heat and will set the mine on fire. Specific gravity 1.5.

9th. Bovey coal. This coal consists of wood penetrated with petroleum or bitumen, and combinations of sulphuric acid. It is found in many parts of the Continent, but is most abundant in England at Bovey, near Exeter, from whence it derives its name.

The foregoing are the kinds of coal commonly known; but the different qualities and proportions of their ingredients make a number of other varieties used for different purposes. Thus various kinds of coals are often found mixed with one another under ground, and some of the finer sorts run like veins between those of a coarse kind. On submitting pit-coal of any kind to distillation, it first yields a watery liquor, then a volatile oil, afterwards a volatile alkali, and lastly, a thick oil; but it is remarkable, that by rectifying this last oil, a transparent and light oil is produced, which, being exposed to the air, becomes black like animal oils.

Perhaps, by dividing the different kinds of pit-coal into fewer classes than those already noticed, the practical gas-light manufacturer's object will be more easily obtained; we shall, therefore, consider that

pit-coal may be divided into three classes according to the proportions of its component parts.

Such coals as are chiefly composed of bitumen, are to be considered as belonging to the *first class*.

Those which contain a lesser proportion of bitumen, and more charcoal, comprehend the varieties of the *second class*.

The *third class* are such as contain very little bitumen, but are chiefly composed of charcoal, chemically combined with different earths.

#### *Remarks upon Coals of the First Class.*

Those coals which come under the first class light without difficulty, burn with a bright and yellowish white blaze during the whole process of combustion. They do not cake nor require stirring; neither do they produce cinders, but are reduced to white ashes. Coals of this class are apt to throw out splinters whilst burning; but, as has been before observed, that may in a great measure be obviated by wetting them before they are used. At the head of this class is to be placed *cannel coal*. Those of Lancashire, and such as are obtained on the north-western coast of England, belong to it. It sometimes occurs in the coal pits of Durham and Northumberland. Most of the varieties of Scotch coal may also be considered as forming part of it, and more particularly the *splent*, which is an inferior kind of *cannel coal*.

Notwithstanding what has been remarked by some

about the quantity of gas obtained from a given quantity of coals by the practical gas engineer, and in the large way too, not being much to be depended upon, as it has from time to time been given to the public either in a tabular form or otherwise, I shall not be deterred from following precisely the same track as was pursued in a former edition of this work, by throwing into a tabular form the results of various experiments made in the large way, under my own particular direction, and which seventeen years of additional experience have tended rather to confirm than otherwise. I shall not stop here to inquire by whom such remarks have been made, that is to say, whether by the mere theorist or by the practical man; but, I may remark that in gas-lighting, as well as in every other art, theory without practice avails little—let them act together, they are most important. For the truth of this remark, all persons who have considered the subject at all will be apt to agree with me, and more particularly such of my readers as are conversant with matters connected with gas; for, every one who has read the evidence of scientific men (theorists only) as given from time to time before various Committees of the House of Commons, when different gas-light Bills were under consideration, must have seen how vastly superior was the evidence given by the practical man on those occasions, though he might be of very inferior scientific attainments.

The following table shows the quantity of gas

obtainable in the manufactory, or in the large way, from several of the different varieties of the *first class* of coals, when ellipsoidal retorts are used and kept at a bright cherry-red heat by day-light; the charge to each retort being about 126 pounds of coal.

Names of Coals.	Number of hours in which one charge is worked off.	Cubic feet of Gas obtained from a Ton of Coals.
Cannel Coal, Scotch . . . . .	4	11,850
Ditto, Lancashire . . . . .	4	11,680
Ditto, Yorkshire . . . . .	4	11,240
Newcastle Coal, Tanfield Moor . . . . .	6	10,070
Gloucestershire Coal, Forest of Dean, High Delph . . . . .	6	9,880
Newcastle Coal, Hartley's . . . . .	6	9,600
Ditto, Cowper's High Main . . . . .	6	9,460
Ditto, Pontops . . . . .	6	9,040
Gloucestershire Coal, Low Delph . . . . .	6	7,660
Ditto, Middle Delph . . . . .	6	7,260
Staffordshire Coal, first kind . . . . .	6	6,474
Ditto, second kind . . . . .	6	6,090
Ditto, third kind . . . . .	6	5,840
Ditto, fourth kind . . . . .	6	5,807

It will be seen on inspecting the foregoing table, that the three species of cannel coal are very productive of gas, and that the charges are worked off in less time than when any of the other coals therein described are used; but the product of coke is of little or no value, it being not only small in quantity but inferior in quality, exceedingly light, and somewhat resembling an indifferent kind of charcoal. When gas procured from this coal is used, it is requisite that the gas-holder should be worked at a very light pressure, and that the flame of the burner

should never be allowed to be more than from an inch and a quarter to an inch and a half in height; for, if these precautions are not taken (as the gas is much richer in bi-carburetted hydrogen than the gas obtained from other descriptions of coal, and thence requiring more oxygen for effecting complete combustion) a considerable portion of it will pass through the burner without being consumed, producing an offensive odour and abundance of smoke, to the annoyance of the parties to whom it is supplied. The holes of the argand burner, with which such gas is used, should be of smaller diameter also than those used where gas is made from the other descriptions of coals.

The gas procured from *cannel coal*, when used with judgment, has a very rich appearance; and, in manufactories where coals are used which are not very productive of gas, it would be highly desirable, when the retorts are worked with 126 pounds of coals for one charge, that one-third of such quantity should be *cannel coal*, which would very much add to the illuminating power of the gas; and, in some cases a greater proportion might be used with advantage.

Of this class of coals, Hartley's are well adapted for heating retorts when set on the furnace plan; but the Tanfield Moor, though generating a very large proportion of heat, is not so, it being very subject to clinker and to burn out the furnace bars

as well as the retorts and the surrounding brick-work.

From various experiments made on the different kinds of Staffordshire coal it is found necessary, for extracting the gas advantageously, to work the retorts at a considerably higher temperature than would have been required, had any of the varieties of the Newcastle coal been submitted to the distillatory process. These coals, as well as the coals from Gloucestershire, when used for making gas, produce a light and porous cake, very inferior in quality to that which is obtained from each of the varieties of the second class of coals.

*Remarks upon Coals of the Second Class.*

Coals of the second class do not burn with so bright a flame as the former. The flame of these coals is of a yellowish tinge. After laying some time upon the fire they become soft and swell; they then cake and produce tubercles, from whence issue small jets of flame. When coals of this kind are burnt in an open grate, the passage of the air through them is prevented by the top of the fire caking, and closely adhering; in consequence, the lower part of the coal contained in the grate is consumed and leaves a hollow, whence, if the upper part were not occasionally broken through, the fire would go out. These coals produce a smaller proportion of ashes than coals of the first class. The

ashes are of a greyish or reddish colour, according to the quality of the earthy part of which the coal is partly formed. They produce hard grey cinders, which, when burnt over again with fresh coals, produce a very strong heat. The colour of the flame produced from this class of coal is not so white and brilliant as that emitted by *cannel coals* and those of similar properties; and that portion of it which is given out after the bitumen it contains is disengaged, is of a pale blue colour. The gas which they produce during this part of the process of combustion, is a mixture of oxide of carbon, hydrogen, and carbonic acid. The coke produced from this class of coal during the process of generating gas therefrom, when carbonization is properly carried on, is well adapted for domestic and culinary purposes; and when such coal is manufactured into coke by means of coke ovens by some gas companies, and in some private gas establishments adopted for heating retorts instead of furnaces, in the ordinary way, it is calculated to be used in the furnaces of iron-founders and for other metallurgical operations. Coals of this class are denominated in the market *strong burning coals*. Smiths prefer the smaller kind of this class of coals before any other, in consequence of its affording the greatest heat, the best cinders, and standing a strong blast. Some of the varieties contain pyrites, others thin layers of limestone and shells; these are found amongst the ashes they

afford as slates and stones. When submitted to distillation, a greater heat is required than is necessary for decomposing *cannel coal*, and some other coals of the first class. The aqueous fluid, which passes over during the process, contains sulphate, carbonate, and hydro-sulphuret of ammonia. When coals of this kind are mixed with those of the first class in the proportion of two-thirds of the former with one-third of the latter, an excellent fuel is thereby formed; and, if on making the mixture the proportion of coals of the first class be increased, the fuel will be more easily managed, and will burn with greater cheerfulness; but its durability will decrease in a like proportion.

The following table shows the quantity of gas obtainable in the manufactory, or in the large way, from several of the different species of this class of coals, when ellipsoidal retorts are used and kept at a heat rather above cherry red by day-light, the charge to each retort being 126 pounds of coal, which will be well worked off in six hours.

Names of Coals.	Cubic feet of Gas obtained from a Ton.
Bewicke and Craister's Wallsend . . . . .	10,370
Russell's Wallsend . . . . .	10,360
Bewicke's Wallsend. . . . .	10,130
Bell's Wallsend . . . . .	9,963
Heaton Main . . . . .	9,740
Killingworth Main . . . . .	9,303
Benton Main . . . . .	9,082
Wigan Orall . . . . .	9,000
Wear Wallsend . . . . .	8,652
Burdon Main . . . . .	8,341

Names of Coals.	Cubic feet of Gas obtained from a Ton.
Brown's Wallsend . . . .	8,336
Wellington Main . . . .	8,270
Temple Main . . . .	8,180
Headsworth . . . .	8,052
Hebburn Seam . . . .	7,896
Hutton Seam . . . .	7,785
Nesham . . . .	7,763
Manor Wallsend . . . .	7,700
Bleyth . . . .	7,420
Eden Main . . . .	6,670
Primrose Main . . . .	6,220
Pembry . . . .	4,200

*Remarks upon Coals of the Third Class.*

Coals of this class require a very high temperature to bring them into ignition; they do not burn till wholly ignited, and then some of the varieties produce a very weak flame; others neither yield flame nor smoke, and merely produce a red heat, like that which is generated by charcoal when undergoing combustion. They contain a very considerable portion of charcoal; they produce only a small quantity of ashes, but these are generally very heavy. Some of the varieties of this class of coals, when distilled in close vessels, produce but very little tar, and the portion which is disengaged is of the consistency of melted pitch: the Kilkenny coal, however, being altogether void of bitumen, produces no tar. Under the distillatory process, most varieties of coals of this class yield a gaseous fluid, composed of gaseous oxide of carbon, hydrogen gas, and a considerable portion of sulphuretted hydrogen.

As it appears by some experiments made on six different species of Welch coal that the best produced, at the maximum, but 1,567 cubic feet of gas from a ton; it is evident that the different varieties of the third class of coals cannot be used profitably for making gas. Amongst the varieties of this class of coals are those found near Kilkenny, the Welch, and the *stone coal*.

The following table is introduced for the purpose of showing the relative proportions of gas obtainable from the different species of coals enumerated in the two preceding tables, the Scotch cannel being considered the standard, and estimated at 1,000.

Scotch Cannel . . . . .	1,000
Lancashire Cannel . . . . .	986
Yorkshire Cannel . . . . .	949
Bewicke and Craister's Wallsend . . . . .	875
Russell's Wallsend . . . . .	861
Bewicke's Wallsend . . . . .	855
Tanfield Moor . . . . .	850
Bell's Wallsend . . . . .	841
Forest of Dean, High Delph. . . . .	834
Heaton Main . . . . .	822
Hartley's . . . . .	810
Cowper's High Main . . . . .	798
Killingworth Main . . . . .	792
Benton Main . . . . .	766
Pontops . . . . .	762
Wigan Orall . . . . .	759
Wear Wallsend . . . . .	730
Burdon Main . . . . .	704
Brown's Wallsend . . . . .	703
Wellington Main. . . . .	697
Temple Main . . . . .	690
Headsworth . . . . .	679
Hebburn Seam . . . . .	666

Hutton Seam . . . . .	657
Nesham . . . . .	655
Manor Wallsend . . . . .	650
Forest of Dean, Low Delph . . . . .	646
Bleyth . . . . .	624
Forest of Dean, Middle Delph . . . . .	612
Eden Main . . . . .	562
Staffordshire Coal, first kind . . . . .	546
Prinrose Main . . . . .	525
Staffordshire Coal, second kind . . . . .	514
Ditto, third kind . . . . .	492
Ditto, fourth kind . . . . .	490
Pembry . . . . .	354

The author trusts the general reader will not find the tables introduced into this chapter uninteresting. To the practical man he knows they must be of importance, for they exhibit the results of a long series of experiments, carefully made, the greater part of them in the large way and all to such an extent as was quite sufficient for obtaining what might be considered as practical results. He is aware that in infant establishments for manufacturing coal-gas, and more particularly in those which have within the last ten years sprung up in all directions in provincial towns, some of very small magnitude, every one concerned in their management cannot be expected to understand, in detail, the operations required, and generally speaking gentlemen forming directories and committees of management do not consider it needful that they should trouble themselves with more than the very outlines of the manufacture ; being content with the management of the financial concerns of the esta-

blishment only ; and leaving the more laborious part attendant upon the carrying on of the works to well-informed servants ; themselves, occasionally, inspecting the apparatus, &c., for the purpose of ascertaining whether there be an appearance of neglect on the part of any one employed. It is thought no one will dispute the necessity which exists for directors and committee men being acquainted fully with everything connected with the works of which they may have the management ; for, if they are not, they must, to a very great extent, be at the mercy of their servants, and be able to form but a very indifferent judgment as to whether every means are laid hold of for carrying on their business on the most economical plan, which the energies of practical and scientific men are continually endeavouring to effect. For instance they may have their retorts so set as to burn out and become useless in a very few months, whereas by a different mode of setting, the retorts still heating as well, and at no increased expense for fuel for heating them, they might last a year or longer ; or the retorts might be so set as either to render it next to impossible to get them to a proper working heat ; or, if such heat could be gained at all, at an enormous expense of fuel, which difficulties might be obviated by their own suggestions, if they informed themselves as to what had been done elsewhere. The same argument would hold good through every part

of the process of generating, washing, condensing, purifying and storing the gas, as well as in its distribution to public or street lamps, or to the private consumer. If they are not acquainted with all these things, they are in a somewhat similar position to a person carrying on any other business with which he is unacquainted—its success must mainly depend upon the persons (therewith acquainted) whom he may employ, and so he must rely upon their judgment instead of his own, to his inconvenience and probable disadvantage. To meet this contingency as well as for other reasons, the author has been induced to bring out this new edition of his work, (the former editions having been long out of print,) and it is his intention so to remodel his matter, where it may require it, as to bring down the information which has been accumulating for some years back relative to the manufacture of gas, to the present time, so that the work may be safely consulted, as one which describes all real improvements of recent date. He has thus far, for reasons already named, been very explicit; and it is his intention as he proceeds to be equally so, divesting his matter as much as possible from all technical phraseology, in order that all who read may clearly comprehend the apparatus he purposes to describe, and as clearly understand all the details relative to the working thereof. In going so fully into the properties of different kinds of coal, he trusts the reader will find some

advantage, inasmuch as it will show him that every description of coal is not equally productive of gas, and should he happen to be a director of a gas company, or a member of the committee of management, it will induce him to pause before large orders are given, and thus prevent what has heretofore occurred, that is to say, the stores of an establishment filled with coals unproductive of gas, and, too late, found to be totally unfit for the purpose intended.

To prevent a recurrence of such an oversight has been the author's motive in furnishing the preceding tables, in addition to which he suggests that gentlemen who are entrusted by the proprietary to manage gas establishments, and who may be about to purchase coals for stock, (whether the coals be named in the tables here given, or otherwise,) to make it an invariable rule not to purchase to any extent, till they have, by experiments upon a few tons at their own works, ascertained the quantity and quality of the gas which may be procured from the coals about to be purchased, as well as the nature of the coke they will produce, and the degree of heat which is necessary for extracting the gaseous matter from them.

I shall conclude this chapter with a few remarks on the probable time that Great Britain may be supplied with coal from the mines of Durham and Northumberland, (independent of the various mines in Yorkshire, Staffordshire, Worcestershire and

other counties,) for the purpose of showing that, however extensive the practice of supplying light by the gas procured from pit-coal may be, there cannot in this country be any apprehension of a scarcity of that material for some centuries yet to come; and may we not presume that before the coal mines are worked out, the All-wise Disposer of events will enable men to provide some other method for obtaining artificial light, which would to us be equally extraordinary, (could we live to witness it,) as a gas-light or a locomotive engine would have been to our ancestors in the fifteenth century, or, without going back so far, to those living less than half a century ago.

In the first edition of this work, (published in the year 1819,) it was stated that the seams of coal worked in Durham and Northumberland, were then equal to a bed twenty miles in length by fifteen in breadth, and the average thickness of the bed was stated to be one yard and a half; also, that from one-fourth to one-sixth would be sufficient to be left as props for supporting the tops of the mines. This being premised, if we make our calculation that one-fifth should be left for the last mentioned purpose; then as 15 miles are equal to 26,400 yards, and 20 miles are equal to 35,200 yards, and the average thickness of the stratum is one yard and a-half; if we multiply 26,400 by 35,200 and again by  $1\frac{1}{2}$ , we shall have for the last product 1,393,920,000

cubic yards of coal contained in the mines above-mentioned; from this we are to deduct one-fifth for pillars to support the roof, the remainder 1,115,136,000 expresses the cubic yards of coal which may, in process of time, be brought to market; and, as each cubic yard of the various species of coal produced from these mines, may be estimated as equal to one ton, consequently the number of cubic yards and of tons are equal. Now as it appears from the Register, that the total annual consumption of coals from Newcastle and Sunderland is about 3,105,000 tons, and as the total quantity of coals which these mines were capable of supplying in the year 1819, was then stated to be 1,115,136,000 tons; therefore if that number be divided by the tons annually consumed, the quotient will express the number of years such supply could then have been given; and taking into consideration that twenty-two years have since elapsed, we may set it down as tolerably near the truth, that those mines will afford a supply of coals for 337 years from this period.

Should objections be made to the above statement, on the ground that a much greater quantity of coal must be used annually since the new mode of procuring light, by means of coal-gas, has been so widely extended, than was consumed heretofore, the author's reply would be that, although many hundred thousand tons of coal are now used every year for making gas; yet in point of fact it would be

altogether incorrect to suppose even one-half of the coal so used, was an additional drain, to that extent even, upon the mines ; for every one knowing any thing about coal-gas making, must be aware that the coke produced in the retorts is capable of giving out more heat after the gas is extracted from the coal than before it underwent such operation ; and that such coke is well adapted for almost every culinary and domestic purpose to which coal itself is applicable. It is hardly needful to add, in support of our position, that the coke produced at the different gas establishments in the metropolis, and elsewhere, is now so well known and so much approved of for use in the kitchen, laundry, &c., that the demand for it is quite commensurate with the quantity produced ; and as whatever coke may be used by the public as fuel, must necessarily equally diminish the quantity of coals which would otherwise be consumed, we can hardly reckon upon a very increased annual consumption since the adoption of gas-lights. The quantity of coal, however, used for fuel in the gas-manufactories, must as a matter of course add to the consumption considerably ; and there has recently been another drain upon the coal mines, by the demand for coke for working locomotive engines upon the numerous railways with which this country is intersected ; still after all we may fairly reckon that the mines we have referred to will not be exhausted for three centuries yet to come—setting aside all

consideration as to the various and extensive coal mines in various parts of this country. It may be remarked further that in several gas establishments there is no loss of coal for fuel; for where the retorts are heated by means of coke ovens, the coals therein used, instead of being burnt away to cinders and ashes, are converted into a very valuable coke.

---

## CHAPTER III.

The Theory of the Combustion of Coal considered, for the purpose of explaining the nature of Gas-light and its production.

WHEN pit-coal is burnt in an open fire-place it emits flame, which is occasionally exhibited in streams of peculiar brightness. This flame is coal-gas in a state of combustion. But besides this gas, there are expelled from coal, by the action of heat, an aqueous ammoniacal vapour, (which on being condensed forms liquid ammonia,) a thick fluid nearly resembling tar, and some non-inflammable gases. The wavering and changing of the colour of flame proceeding from a coal fire, is occasioned by the variety of products which coal affords; and as these are evolved, we have at one time streams of brilliant light, at another clouds of dense and aqueous vapour thrown off as smoke. Seeing, then, that when coals are burnt in the ordinary way we have evident proofs that they contain inflammable gas, which, if collected and properly applied, would serve as a substitute for the lights obtained by using candles or oil, together with other valuable products, we must be aware that whenever they are distilled in close vessels the various parts of which they are formed may be collected. Such part of the coal as is bituminous will

melt out and be partly converted into gas as it is evolved in a state of vapour, the residue will be exhibited in the form of tar. That which contains ammoniacal salts will be thrown off as vapour, and, on condensation, will appear as an amber-coloured fluid, more or less charged with ammonia, according to the circumstances under which the distillation may have been carried on, and the quality of the coal. Whilst the above products are evolved, a considerable quantity of carburetted hydrogen gas (or more properly speaking coal-gas) and some unflammable gases are also generated. These having all been freed from the coal by the action of heat, and collected in their respective reservoirs, its base, which is a carbonaceous substance, known by the name of coke, remains in the retort, or distillatory vessel. The coal-gas, being freed from the sulphuretted hydrogen and non-inflammable gases, is fit for use, and may be forced out of the gas-holder where it is collected to any distance, by means of cast-iron pipes laid under ground; from whence smaller pipes of wrought iron, of drawn tin, or of copper, convey it to the respective burners in the houses, &c., where gas is used. At the extremity of the pipes are fixed the burners, to which, by means of stop cocks, the gas is admitted, and through orifices made in the burners it escapes and is ignited for the purpose of affording light. Thus from pit-coal, a mineral raised in considerable quantities

in this country, is obtained a substitute for such lights as are afforded by using wax, tallow, or oil, but of a far superior quality and at an immense saving of expense. When this is considered, it cannot but be gratifying to the feelings of every Englishman to know that, within his native country, there are abundant resources for generating artificial light; and, that he is no longer entirely dependent on the relations he holds with foreign powers, or on the fisheries, for a supply of such materials as were heretofore exclusively used for producing it.

The early promoters of gas-lighting rested their claims to public notice and encouragement on precisely the same grounds as the gas companies of the present day; that is to say, on the ease with which the various products obtainable from coal are collected and the cheap rate at which they can afford to sell them, but more particularly the article of gas. They considered the flame which pit-coal yields when it is consumed in the ordinary way is turned to very little advantage, being frequently confined to one place and there of much less use than a red heat would be. They noticed also that it was often obscured and smothered by the quantity of incombustible matter which was thrown off with it, and from which a considerable portion of the coal-gas generated is not applied to any useful purpose.

If we direct our attention to the process of the combustion of coal, when burnt in a common grate, we shall very frequently observe streams of flame burst out of the clouds of smoke which are evolved; these suddenly disappear and fresh ones supply their place as the quantity of inflammable gas preponderates over the non-inflammable gases and aqueous products. Should we apply a lighted taper to the small jets issuing from that part of the coal from whence the tar oozes and which it points out as bituminous they will ignite and burn with a brilliant flame. In short, it is quite evident that a considerable quantity of gaseous matter, which is capable of generating both light and heat in open fire-places, must escape up the chimney, leaving but a portion of it to be exhibited as flame.

If we compare the theory of the production of gas-light with the theory of the production of artificial light by means of candles or of lamps, we shall instantly perceive that the principles are similar; for, in candles or lamps, the wick bears a like situation to that of coal when submitted to distillation in a close vessel. The wick of a candle serves to convey the melted tallow by capillary attraction to where it is to be consumed. It is there decomposed and forms carburetted hydrogen gas; as this is made use of a fresh supply is constantly kept up, which maintains the flame. By a parity of reasoning, it appears that the burning of oil in a lamp depends

on similar circumstances. The oil of a lamp is drawn up through the wick, and is formed as coal in a retort into that carburetted hydrogen gas from whence proceeds illumination. After considering these matters it may be asked, though now rather late in the day to make such inquiry, What do gas-light companies profess to accomplish? To such a question the following is an answer. They profess to generate such quantities of gas as may be wanted for supplying that district or place where their works may be situated with a very superior description of artificial light, by means of a sufficient number of retorts, gas-holders, and other necessary apparatus; and that this gas is precisely the same sort of material as the flame of a candle or lamp, being, however, more safe than either, of higher illuminating power, capable of forming various devices, and, quantum of light for quantum of light, vastly cheaper. The difference between obtaining light from candles and lamps and from coal-gas is this: when coal-gas is used as a substitute for light afforded by the combustion of tallow or oil in the raw state, the distillatory process for lighting streets and districts, nay whole towns and large cities, is carried on in one place, perhaps far from where the light may be wanted; whilst, by the action of candles or lamps, the process is performed wherever such candle or lamp may be used, namely, at their respective wicks. We may,

perhaps elucidate this matter still more by observing, that the production of artificial light for illuminating purposes is brought about by one way or another by the agency of heat. When gas for illumination is to be obtained from coal, the retort, or distillatory vessel, is first heated by the fire over which it is placed till it becomes sufficiently hot for decomposing the coal. When it is so, the coal is introduced into it, and the atmospheric air being excluded, the heat of the retort being kept up acts upon the coal within it, and thereby the gaseous and vaporous products are evolved, which pass off through the different parts of the apparatus, the useless and noxious constituents thereof being arrested in their passage through them, and the carburetted hydrogen gas alone transmitted to the gas-holder in a sufficiently pure state for the purposes of illumination. From the gas-holder this is forced by pressure through pipes at any time and to any distance required for the use of the consumer.

In concluding this chapter, we are to observe that the system of generating light from pit coal is supported not only by reason, but now by long experience also; that the discovery ranks highly amongst those which have within the last half century been made in chemistry, and it appears calculated to produce still more favourable results than any we have yet witnessed from its use; for from its application we have learnt that those uses to

which we have been accustomed to put coals, tallow, and oil, are not all to which it is applicable. The production of artificial light from coal, as it relates to our comforts, is of no small importance, and the source afforded for obtaining it by means of gas is in this country abundant. By the introduction of the gas-lights the process of analyzing coals, which was formerly confined to the laboratory of the chemist, is now in the large way performed with the greatest simplicity at any gas-light establishment. Indeed, so much has the scheme extended itself, that there are now in London, Westminster, Southwark, and environs alone (as recently stated by *Dr. Ure, in his Dictionary of Arts, Manufactures, and Mines*) eighteen public gas-works belonging to twelve different gas companies, with a capital employed in works, pipes, tanks, gas-holders, apparatus, &c. amounting to 2,800,000*l.*, from whence is derived a yearly revenue of 450,000*l.* It is further stated, 180,000 tons of coal are used annually for making gas, and that such coal produces 1,460,000,000 cubic feet of gas. The London Companies have about 40,000 private consumers to supply with gas, who altogether use about 134,300 burners. There are 2,650 public or street lamps supplied with gas in the city of London, and 27,750 in the city of Westminster, the borough of Southwark, and the environs. There are 380 lamp-lighters; and, altogether, about 2,500 persons are employed in the

metropolis alone in this branch of manufacture. The aggregate number of gas-holders is 176, several of them telescopic, or double ones, which are capable of storing 5,500,000 cubic feet. 890 tons of coals are said to be used in the retorts on the shortest day (say 24th December) in twenty-four hours, and during the evening and night of that day there are 7,120,000 cubic feet of gas used. Between 1822 and 1827 the quantity of gas generated in one year nearly doubled itself, and that in five years, and between 1827 and 1837 it doubled itself again, and the demand for it is still very rapidly increasing.

---

## CHAPTER IV.

An Historical Statement of the successive Discoveries which have been made in Decomposing Coal, and on the Rise and Progress of the application of Coal-Gas as a substitute for Wax, Tallow, or Oil, as a means of illumination.

BEFORE we commence describing the different kinds of apparatus and machinery used for the purpose of generating coal gas, it is presumed some readers will feel an interest in knowing when and in what way the first idea of applying coal gas to the purpose of affording light originated ; and also in having described to them, in as concise a manner as the subject will admit of, the gradations through which it has risen till it reached its present pre-eminence over every artificial light hitherto known, both as relates to the quantity and quality of the light thereby afforded and the cheap rate at which it can be supplied. From this abridged history there will be seen the necessity of a considerable lapse of time to mature and introduce new systems, the difficulty with which improvements in science are so established as to become universally adopted, and the slowness with which mankind follow after known principles that forward something which may be considered as an innovation upon former and long established habits.

That a permanently elastic and *inflammable* æri-form fluid is evolved from pit-coal appears to have been first *experimentally* ascertained by the Rev. Dr. John Clayton, Dean of Kildare. With the exact date of the discovery we are not acquainted: but, as the communication made to the Earl of Egmont, F.R.S., in 1739, by Dr. Robert Clayton, Bishop of Cork and Orrery, purported to be an extract of a letter from the discoverer to the Hon. Robert Boyle, who died in 1691, the discovery must have been made prior to that event, though not published in the *Philosophical Transactions of the Royal Society* till the year 1739.

The coal-evolved gases, however, were known to miners even before the formation of the Royal Society, from the direful effects they produced, and were by them termed *choke-damp* (carbonic acid gas) and *fire-damp* (carburetted hydrogen gas). The earliest account which the Royal Society has published relative to either is in their Transactions for the year 1667; it is entitled, “A Description of a Well and Earth in Lancashire taking fire by a Candle approached to it; imparted by Thomas Shirley, Esq., an eye witness,” and is as follows:—

“About the latter end of February, 1659, returning from a journey to my house in Wigan, I was entertained with the relation of an odd spring situated in one Mr. Hawkley’s ground (if I mistake not), about a mile from the town, in that road which

leads to Warrington and Chester. The people of this town did affirm that the water of this spring did burn like oyle; into which error they suffered themselves to fall for want of due examination of the following particulars; for, when I came to the said spring (being five or six in company together) and applied a lighted candle to the surface of the water, 'tis true there was suddenly a large flame produced, which burnt vigorously; at the sight of which they began to laugh at me for denying what they had positively asserted. But I, who did not think myself confuted by laughter grounded upon inadvertency, began to examine what I saw; and observing that this spring had its eruption at the foot of a tree growing on the top of a neighbouring bank, the water of which filled a ditch that was there, and covered the burning place lately mentioned; I then applied a lighted candle to divers parts of the water contained in the said ditch, and found, as I expected, that upon a touch of the candle and the water the flame was extinct. Again, having taken up a dish full of water at the flaming place and held the lighted candle to it, it went out; yet I observed that the water at the burning place did boyle and heave like water in a pot upon the fire, though my hand put into it perceived it not so much as warm. This boyling I conceived to proceed from the eruption of some bituminous or sulphureous fumes, considering this place was not above

thirty or forty yards distant from the mouth of a coal-pit there. And, indeed, Wigan, Ashton, and the whole country, for many miles' compass, is underlaid with coal. Then applying my hand to the surface of the burning place of the water, I found a strong breath, as it were a wind, to bear against my hand. Then I caused a dam to be made, and thereby hindering the recourse of fresh water to the burning place; I caused that which was already there to be drained away; and then applying the burning candle to the surface of the dry earth at the same point where the water burned before, the fumes took fire and burned very bright and vigorous. The cone of the flame ascended a foot and a half from the superficies of the earth. The basis of it was of the compass of a man's hat about the brims. I then caused a bucket full of water to be poured on the fire, by which it was presently quenched, as well as my companions' laughter was stopped, who began to think the water did not burn. I did not perceive the flame to be discoloured like that of sulphureous bodies, nor to have any manifest scent with it. The fumes, when they broke out of the earth and prest against my hand, were not, to my remembrance, at all hot."

The above extract has been made partly under an idea that it may not be uninteresting to the general reader, as being one of the most early records of the action of what was, no doubt, carburetted hydrogen

gas generated from natural causes; and it will be seen in its proper place, when the experiments of Dr. Clayton are given (which it is proposed to furnish in the Doctor's own words), that in all probability his attention was directed to the matter by observing the very same spring which Mr. Shirley speaks of.

Dr. Priestley states, in his *Observations and Experiments on Air*, published in 1790, that "Mr. Boyle was the first who discovered that what we now call *fixed air* and *inflammable air* are really *elastic fluids*, capable of being exhibited in a state unmixed with common air." There is no record, however, of either having been obtained from coal by distillation prior to the time of Dr. Stephen Hales, the ingenious author of a work on *Vegetable Statics*, published in 1726; yet, although there be no positive record, Dr. Clayton's letter, without date, to Mr. Boyle, as already referred to, shows it must have been written in Mr. Boyle's life-time, consequently antecedent to Dr. Hales's experiments. Dr. Hales states, that "from the distillation of 158 grains of Newcastle coal he obtained 180 cubic inches of air, which weighed 51 grains, being nearly one-third of the whole." His experiments were made, however, for the purpose of ascertaining the elasticity of air produced by the distillation of coal, and consequently its inflammable and other properties were not inquired into.

Before we notice Dr. Clayton's experiments, we shall mention some circumstances relative to the properties of coal gas as given in the Philosophical Transactions for 1733. The paper is headed "An account of the damp air in a coal-pit of Sir James Lowther, sunk within twenty yards of the sea," dated, "Whitehaven, August 1st, 1733."

"Sir James Lowther having occasion to sink a pit near the full sea-mark, for the draining of one of his principal collieries near Whitehaven, in the county of Cumberland, which was known would be near eighty fathom in depth to the best seam of coals, which is three yards thick. The work was carried on day and night very successfully, through several beds of hard stone, coal, and other minerals, till the pit was sunk down forty-two fathom from the surface, where they came to a bed of black stone, about six inches thick, very full of joints and open cliffs, which divided the stones into pieces of about six inches square, the sides whereof were all spangled with sulphur, and in the colour of gold. Under this black stone lies a bed of coal, two feet thick. When the workmen first pricked the black stone bed, which was on the rise side of the pit, it afforded very little water, contrary to what was expected; but instead thereof, a vast quantity of damp, corrupted air, which bubbled through a quantity of water then spread over that part of the pit, and made a great hissing noise; at which the workmen, being some-

what surprised, held a lighted candle towards it, and it immediately took fire upon the surface of the water and burned very fiercely, the flame being about half a yard in diameter and near two yards high, which frightened the workmen, so that they took the rope and went up the pit, having first extinguished the flame by beating it out with their hats. The steward of the works being made acquainted with it, went down the pit with one of the men, and holding a candle to the same place, it immediately took fire again as before, and burnt about the same bigness, the flame being blue at the bottom and more white towards the top. They suffered it to burn for nearly half an hour; and no water being drawn in the time, it rose and covered the bottom of the pit near a yard deep, but that did very little abate the violence or bulk of the flame, it still continuing to burn upon the surface of the water. They then extinguished the flame as before, and opened the black stone bed near two feet broad, that a greater quantity of air might issue forth, and then fired it again; it burned a full yard in diameter and about three yards high, which soon heated the pit to so great a degree that the men were in danger of being stifled, and so were as expeditious as possible in extinguishing the flame, which was then too strong to be beaten out with their hats; but with the assistance of a spout of water of four inches in diameter, let down from a cistern above, they

happily got it extinguished without further harm. After this no candles were suffered to come near it till the pit was sunk down quite through the bed of black stone, and the two foot coal underneath it ; and all that part of the pit, for four or five feet high, was framed quite round, and very close jointed, so as to repel the damp air, which, nevertheless, it was apprehended, would break out in some other adjoining part unless it was carried off as soon as produced out of the cliffs of the stone ; for which end a small hollow was left behind the framing, in order to collect all the damp air on one side of the pit, where a tube of about two inches square was closely fixed, one end of it into the hollow behind the framing and the other carried up into the open air, four yards above the top of the pit ; and through this tube the said damp air has ever since discharged itself without being sensibly diminished in its strength or lessened in its quantity since it was first opened, which is now two years and nine months ago. It is just the same in summer as in winter, and will fill a large bladder in a few seconds by placing a funnel at the top of the tube, with the small end of it put into the neck of the bladder, and kept close with one's hand.

“ The said air being put into a bladder, as is above described, and tied close, may be carried away and kept some days, and being afterwards pressed gently through a small pipe into the flame of a

candle, will take fire and burn at the end of the pipe as long as the bladder is gently pressed to feed the flame, and when taken from the candle after it is so lighted, it will continue burning till there is no more air left in the bladder to supply the flame. This succeeded in May last, before the Royal Society, after the air had been confined in the bladder for near a month.

“ The air, when it comes out at the top of the tube, is as cold as frosty air.

“ It is to be observed, that this sort of vapour or damp air will not take fire except by flame; sparks do not affect it, and for that reason it is frequent to use flint and steel in places affected with this sort of damp, which will give a glimmering light that is a great help to the workmen in difficult cases.

“ After the damp air was carried up in a tube, in the manner above described, the pit was no more annoyed with it, but was sunk very successfully through several beds of stone and coal, without any other accident or interruption, till it came to the main seam of coals, which is three yards thick and seventy-nine fathom deep from the surface; and the said pit being oval, viz., ten feet one way and eight the other, it serves both for draining the water by a fire-engine and also for raising the coals.”

Notwithstanding the preceding communication to the Royal Society, and the exhibition of the gas brought from Whitehaven before its members, it

does not appear that the scientific men of that day made any effort whatever to ascertain how a similar gas might be produced, or offered any suggestion as to the gas itself being applied to any useful purpose. The narrator describes with great precision some of the properties of coal-gas, such, for instance, as its elasticity and inflammability after being kept for some time, and that it would not ignite by means of sparks nor otherwise than by being brought into contact with flame; properties which it is well known are characteristic of coal-gas.

Having spoken of Mr. Shirley's observations, and given the preceding narrative, we shall now give Dr. Clayton's account of what led him to think of distilling pit-coal and the results which arose out of that attempt; and as no language of ours could furnish a more clear, distinct, and intelligible account than what the Doctor gave himself, (*see Philosophical Transactions of the Royal Society for the year 1739, Vol. XLI.*), we cannot do better than transcribe the same for the perusal of our readers:—

“Having seen a ditch within two miles of Wigan, in Lancashire, wherein the water would seemingly burn like brandy, the flame of which was so fierce that several strangers have boiled eggs over it, the people thereabouts, indeed, affirmed that about thirty years ago, it would have boiled a piece of beef; and that whereas much rain formerly made it burn fiercer, now after rain it would scarcely burn at all.

It was after a long continued season of rain, that I came to see the place, and make some experiments, and found accordingly that a lighted paper, though it were waved all over the ditch, the water would not take fire. I then hired a person to make a dam in the ditch and fling out the water, in order to try whether the steam which arose out of the ditch would then take fire, but found it would not. I still, however, pursued my experiment, and made him dig deeper; and when he had dug about the depth of half a yard, we found a shelly coal, and the candle being then put down into the hole, the air caught fire and continued burning.

“I got some coal, and distilled it in a retort in an open fire. At first there came over only phlegm, afterwards a black *oil*, and then likewise a *spirit* arose, which I could no ways condense; but it forced my lute or broke my glasses. Once, when it had forced my lute, coming close thereto in order to try to repair it, I observed that the spirit which issued out caught fire at the flame of the candle, and continued burning with violence as it issued out in a stream, which I blew out and lighted again, alternately, for several times. I then had a mind to try if I could save any of this spirit; in order to which, I took a turbinated receiver, and putting a candle to the pipe of the receiver, whilst the spirit arose, I observed that it caught flame, and continued burning at the end of the pipe, though you could not discern what fed the flame. I then blew it out

and lighted it again several times; after which I fixed a bladder, squeezed and void of air, to the pipe of the receiver. The oil and phlegm descended into the receiver, but the spirit, still ascending, blew up the bladder. I then filled a good many bladders therewith, and might have filled an inconceivable number more, for the spirit continued to rise for several hours, and filled the bladders almost as fast as a man could have blown them with his mouth, and yet the quantity of coals distilled was considerable.

“ I kept this spirit in the bladders a considerable time, and endeavoured several ways to condense it, but in vain; and when I had a mind to divert strangers or friends, I have frequently taken one of these bladders and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising, because no one could discern any difference between these bladders and those which are filled with common air.

“ But then, I found that this spirit must be kept in good thick bladders, as in those of an ox, or the like; for, if I filled calves’ bladders therewith, it would lose its inflammability in twenty-four hours, though the bladders became not relaxed at all.”

Clear and intelligible as is the account which Dr.

Clayton gives of his discovery—a discovery in which some of the most striking and valuable properties of coal-gas must have arrested his attention—still it would appear he himself had no idea as to how it might be usefully employed. It would appear also that the discovery did not, at the time of his promulgating it, attract any particular notice.

Dr. Richard Watson, (afterwards Bishop of Llandaff,) in the year 1767, published the result of his researches on the subject of obtaining gas from coal, in the second volume of his *Chemical Essays*, from which it would appear he examined the qualities of the gaseous and other products, generated whilst distilling pit-coal; and observed, that the carburated hydrogen gas would not only inflame as produced, when allowed to issue from the distillatory vessel, but that its inflammable property was retained after passing it through water and allowing it to ascend by means of curved tubes. The other products obtained during the process were an ammoniacal liquor, a thick oil resembling tar and coke.

On taking a review of what has been already said relative to the observations which had been made upon gas naturally produced, and the experiments which had been instituted for obtaining gas by distillation from pit-coal, we shall find that about a century elapsed from the time of Mr. Shirley noticing the burning ditch near Wigan, and that of

Dr. Watson making his experiments without any useful results being produced. Another quarter of a century passed away before the application of gas obtained from coal and other substances was thought of as a substitute for candles and lamps, for it was not till the year 1792 that Mr. Murdoch, who then resided at Redruth, in Cornwall, commenced a series of experiments upon the quantity and quality of the gases contained in different substances. The following account of his discovery is given by Dr. W. Henry, of Manchester, in Thomson's *System of Chemistry*, vol. i., p. 52.

“ In the course of his experiments, he remarked that the gas obtained by distillation from coal, peat, wood, and other inflammable substances, burnt with great brilliancy upon being set fire to; and it occurred *to him*, that by confining and conducting it through tubes, it might be employed as an economical substitute for lamps and candles. The distillation was performed in iron retorts, and the gas conducted through tinned iron and copper tubes, to the distance of seventy feet. At this termination, as well as at intermediate points, the gas was set fire to as it passed through apertures of different diameters and forms, purposely varied with a view of ascertaining which would answer best. In some, the gas issued through a number of small holes like the head of a watering pan, in others it was thrown out in thin long sheets; and again, in

others in circular ones, upon the principle of Ar-gand's lamp. Bags of leather and of varnished silk, bladders, and vessels of tinned iron, were filled with the gas, which was set fire to and carried about from room to room with a view of ascertaining how far it could be made to answer the purpose of a moveable or transferable light. Trials were likewise made of the different quantities and qualities of gas produced by coals of various descriptions, such as the Swansea, Haverfordwest, Newcastle, Shropshire, Staffordshire, and some kinds of Scotch coals.

“ Mr. Murdoch's constant occupations prevented his giving further attention to the subject at that time ; but he again availed himself of a moment of leisure to repeat his experiments upon coal and peat at Old Cumnock, in Ayrshire, in 1797 ; and it may be proper to notice, that both these and the former ones were exhibited to numerous spectators, who, if necessary, can attest them. In 1798, he constructed an apparatus at Soho foundry, which was applied, during many successive nights, to the lighting of the building, when the experiments upon different apertures were repeated and extended upon a larger scale. Various methods were also practised of washing and purifying the air to get rid of the smoke and smell. These experiments were continued, with occasional interruptions, until the epoch of the peace in 1802, when the illumination of the Soho

manufactory afforded an opportunity of making a public display of the new lights; and they were made to constitute a principal feature in that exhibition."

Thus far we have followed Dr. Henry; but, to put the matter in a still clearer point of view as to what induced Mr. Murdoch to think of substituting gas so obtained for candles or lamps, we will take his own account, as given in the Philosophical Transactions for 1808, and in vol. xxi. of Nicholson's Journal. He states:—

"It is now nearly sixteen years since, in a course of experiments I was making at Redruth, in Cornwall, upon the quantities and qualities of different kinds of gases, produced by the distillation from different mineral and vegetable substances, *I was induced, by some observations I had previously made upon the burning of coal, to try the combustible property of the gases produced from it, as well as from peat, wood, and other inflammable substances; and, being struck with the great quantities of gas which they afforded, as well as with the brilliancy of the light, and the facility of its production, I instituted several experiments with a view of ascertaining the cost at which it might be obtained, compared with that of equal quantities of light yielded by oils and tallow.*"

He then narrates the progress of his experiments

to the same effect as we have already given them, and adds,—

“ At the time I commenced my experiments I was certainly unacquainted with the circumstance of the gas from coal having been observed by others to be capable of combustion; but I am since informed that the current of gas escaping from Lord Dundonald’s tar-ovens had been frequently fired; and I find that Dr. Clayton, in a paper in vol. xli. of Transactions of the Royal Society, so long ago as the year 1739, gave an account of some observations and experiments made by him, which clearly manifest his knowledge of the inflammable property of the gas, which he denominates the spirit of coals; *but the idea of applying it as an economical substitute for oils and tallow does not appear to have occurred to this gentleman; and I believe I may, without presuming too much, claim both the first idea of applying, and the first application of this gas to economical purposes.*”

It has been considered expedient to be rather full in explaining the steps which intervened between the period of Mr. Shirley’s observations and that when a new era began to dawn under the scientific researches of Mr. Murdoch, who, in himself connecting the two great links of science and practice, achieved what the theorist alone would perhaps have scarcely thought of—at all events, what

scientific men during a period of one hundred and twenty-five years had not effected.

Prior to the first edition of this work being published, a popular author of the day (Mr. Accum) had given the credit of the first application of coal gas as a substitute for candles and lamps to Mr. F. A. Winsor, who exhibited the general nature of gas-light illumination at the Lyceum Theatre, London, in the years 1803 and 1804; but the apparatus by the means of which he obtained coal gas, and the mode of purification which he adopted, he kept a secret. He showed the manner of conveying the gas through the house, and exhibited various devices for chandeliers and burners. Instead of copper pipe, or, what is far superior, the drawn tin tubing, now almost exclusively used, he proposed long flexible tubes brought from the ceiling or the wall, to the ends of which were attached different descriptions of burners. He proved experimentally that the flame of coal gas, when properly managed (by allowing no more gas to pass through the burner than can be entirely consumed), produces no smoke; and that it is not, as the flame from candles or lamps, subject to emit sparks, and therefore not so dangerous; nor is it so liable to be put out by sudden gusts of wind or by heavy rain.

It is expected that no one who is at all acquainted with the rise and progress of this new branch of manufacture would wish to deprive Mr. Winsor of

the credit he very justly claims of being highly instrumental in bringing the utility of gas-lights before the attention of the public ; for it must be admitted that but for his persevering labours, both as a lecturer and a writer, on the subject of gas, the thing might have remained to this day as a philosophical plaything, and rendered no real benefit to the public ; it being probable that Mr. Murdoch was too much occupied by other avocations to admit of his devoting so much time to this matter as it required for drawing towards it that public attention which was essentially necessary. It is, therefore, willingly admitted that Mr. Winsor did much as a promulgator, having to overcome great difficulties whilst lecturing at the Lyceum Theatre, partly from the circumstance of his being a foreigner, which rendered it necessary that he should employ a person to read his lectures to his audience, and partly from the character of his mechanical assistants, who were generally such as were unable to render him such services in his pursuits as were required. Notwithstanding these unfavourable circumstances, Mr. Winsor persevered in endeavouring to carry out his plans, and removed his exhibition to Pall-mall, where, early in 1807, he lighted up a part of one side of the street with gas, which was the first instance of that kind of light being applied to such a purpose in London. He projected a national light and heat company ; and,

having obtained a patent, he published some pamphlets to recommend it. It is not our business to enter into long inquiries as to how the statements he made were fallacious; but we may, as they appear curious, mention some of them. He informed the public that a deposit of five pounds in the National Light and Heat Company would secure to the person subscribing it a handsome annual income. We were not to have any more smoke in London, or throughout the country, when once his plans were carried out; consequently, as he expressed it, that *unchristian-like* employment of chimney-sweeper would be at an end. But what was the most attractive to many arose out of the immense profits which were certain of being divided by the shareholders; for, if a single five pounds deposit would secure to the depositor a handsome annual income (we shall be more moderate in our calculations than was Mr. Winsor, and reckon it at only 20*l.* per annum), it might reasonably be expected that many would be ready to make a venture, and many did do so, but without ever realizing the advantages the patentee had held out, whose patent, amongst other very desirable objects, was to effect the paying off of the national debt, and afterwards (besides enriching the proprietors of the company he was desirous of seeing formed) the revenue was to be increased by a tax upon the products obtained from coal in the gas-manufactories more than com-

mensurate to that arising from the tax upon candles. Plausible, however, as Mr. Winsor's statements were, none of the advantages he held out have as yet been realized, nor is it very probable they ever will be; and, although nearly fifty thousand pounds were subscribed in five pound shares, for establishing his New Light and Heat Company, he was not enriched, for he expended the whole in endeavouring to carry out his projects. Sanguine in his expectations, indefatigable in his exertions, and zealous in the cause, he directed all the talents and energies he possessed towards one grand object, and thus achieved much for the public good; but, with all his ardour, his skill, and his exertions, he, like many others, achieved but little towards promoting his own comforts or the comforts of his family. The public, however, have been benefited to no small extent by what he did; and though we cannot name him as the original discoverer of this new mode of supplying light, we think his name ought to be had in remembrance for having done much to hasten its adoption. It is not necessary to say more with respect to Mr. Winsor than that he kept his position with the company which he had mainly been the means of forming for some years, but without forwarding his scheme very considerably.

Attention having been awakened, we find that in 1804, whilst Mr. Winsor was lecturing in London, Mr. (afterwards Dr.) William Henry, in 'a course

of lectures on chemistry which he delivered in Manchester, showed the method of producing gas from coal, and illustrated how readily and advantageously it might be used as a means for affording light; and it is probable his lectures were the means of introducing gas-lighting into some large concerns in Manchester and its immediate neighbourhood. He was one of the first amongst the chemists of eminence who analyzed the composition and investigated the properties of coal-gas with scrupulous accuracy; and that his experiments, which were numerous, and extended not only to gas procured from coal, but also from wood, peat, oil, wax, &c. (the results of which were published in 1805, and various other papers written by him appeared afterwards in the *Philosophical Transactions*, and also in several periodicals) tended to make the subject of gas-lighting a more frequent object of discussion amongst scientific men, there is little doubt.

In the year 1805, Mr. Northern, of Leeds, called the attention of the public to applying coal gas for the purpose of producing light instead of candles, &c. An account of what he did is extracted from the *Monthly Magazine* for April, 1805:—

“I distilled,” he says, “in a retort fifty-six ounces of pit-coal in a red heat, which gave six ounces of a liquid matter covered with oil, more or less fluid as the heat was increased or diminished. About twenty-six ounces of cinder remained in the retort;

the rest came over in the form of air, as it was collected in the pneumatic apparatus. I mixed part of it with atmospherical air, and fired it with the electric spark with a tolerable explosion, which proves it to be hydrogen. Whether any other gases were mixed with it I did not then determine. In the receiver I found a fluid of an acid taste, with a great quantity of oil, and at the bottom a substance resembling tar.

“The apparatus I make use of for producing light is a refiner’s crucible, the top of which, after filling with coal, I close with a metal cover, luted with clay or other luting, so as to prevent the escape of the gas; a metal pipe is soldered into the cover, bent so as to come under the shelf in the pneumatic trough, over which I place a jar with a stop-cock and a small tube, the jar being previously filled with water; the crucible I place on the common or other fire, as is most convenient; and as the heat increases in it, the gas is forced rapidly through the water into the jar, and regularly displaces it. I then open the cock and put fire to the gas, which makes its escape through the small tube, and immediately a most beautiful flame ensues, perfectly free from smoke or smell of any kind. A larger light, but not so vivid or clear, will be produced without passing the gas through water, but attended with a smoke somewhat greater than that of a lamp charged with common oil.

“ I have great hopes that some active mechanic or chemist will, in the end, hit on a plan to produce light for large factories and other purposes at a much less expense, by the above or similar means, than is at present produced from oil.”

As a preliminary step towards the hopes of Mr. Northern being realized, Mr. Samuel Clegg, who had at the works of Boulton and Watt, at Soho, directed his attention to the construction of gas-light apparatus, communicated to the Society of Arts an account of his method of lighting up manufactories with gas, for which he received the silver medal; which, although but a small token of the general estimation of this new branch of manufacture, if we consider the rapid advances it has since made, yet might at that time have been thought sufficient for the information afforded. As to Mr. Clegg the gas-light manufacturer is indebted for various improvements in apparatus and machinery, we shall give the account of his inventions between 1805 and 1817, given by himself in a small pamphlet published several years ago. He says—

“ My attention was first directed to the preparation of gas for the purposes of illumination in the year 1804. In 1805 I erected a gas apparatus at the cotton-mill of Henry Lodge, Esq., near Halifax, which was the first in the kingdom. In 1806 I lighted his dwelling-house, where I first attempted to purify the gas by lime introduced into the tank

in which the gasometer floated. In 1807 I lighted the manufactory of Messrs. T. and S. Knight, of Longsight, near Manchester. In 1809 I erected a gas apparatus in a large manufactory at Coventry, belonging to Mr. Harris, in which I introduced a paddle at the bottom of the tank to agitate the lime. In 1811 I lighted a large manufactory at Dolphinholme, near Lancaster, by means of an apparatus similar to what I had erected at Coventry. In the same year I erected an apparatus at Stonyhurst College, Lancashire (here I exhibited the portable lamps by condensing the gas in a copper globe), where I introduced a lime-machine, the first ever employed for that purpose\*—a machine which has been universally adopted, and which has rendered the introduction of gas practicable in any situation. In that year, also, I lighted a large cotton-mill in Manchester, belonging to Mr. Greenway, where I first introduced the hydraulic pipes for isolating the retorts, a plan now in general use. In 1812, when the extensive cotton-mills belonging to Mr. Samuel Ashton and Brothers, at Hyde, near Stockport, were lighted, I introduced the lime-machine and the hydraulic mains with increased effect. Here the twelve inch cylindrical retorts and improved mouth-pieces were first introduced. Here also I first attached to the gasometer the mechanism for regulating its specific gravity. In the same year I

\* The wet lime purifier.

lighted the premises of Mr. Akerman, in the Strand. In 1813 I undertook the direction of the different gas-works belonging to the Chartered Gas-light Company in London and Westminster, and during the four following years lighted a great part of both cities. In the course of that period I invented and adopted the rotative retorts, the semi-fluid lime-machine, the rotative and reciprocating gas-meter, the governor or regulator, and an apparatus for the decomposition of oil, tar, &c. In 1817 I invented the collapsing gas-holder. In that year also I erected a gas apparatus at His Majesty's Mint; and since that time I have lighted several towns, including Bristol, Birmingham, Chester, &c."

In giving Mr. Clegg's statement of what he performed during the first twelve years after the manufacture of gas had begun to claim the attention of the public, we admit having passed over what others were doing during the same period; but we trust we shall not be accused of neglecting others and speaking of Mr. Clegg exclusively. Should we, however, be so, our answer is, the undeniable preponderance of his claims to notice over those of others, arising from his having erected the first gas-works in the kingdom, put up the first purifier, and been the first to introduce the mode of isolating the retorts by means of the hydraulic main, dip and H pipes. Had he done nothing more, his name must

stand high among those of engineers connected with gas companies.

We must not, however, dwell longer upon Mr. Clegg's inventions here, but turn for a time towards what others were meanwhile doing. We find that in 1806 Mr. Josiah Pemberton, who had for some time been contriving and constructing gas apparatus, exhibited the gas-lights in a variety of forms and with great effect at the front of his manufactory, in one of the principal streets of Birmingham. His apparatus was simple in construction and arrangement, consisting of a cast iron vessel something similar to an iron pot, which was set in brick-work like a common boiler. It had a strong cover of the same material fitted to its top, to which was attached the pipe that conveyed the gas away as it was produced to a square cistern containing water, which cistern was divided by several vertical partitions, which obliged the gas to ascend and descend in its passage through the water, so as to be well condensed and washed before it reached the gasometer, which was suspended in a large wooden vat and fitted with a counterpoise or weight to take off part of its pressure. He erected gas apparatus in the way of business for Mark Saunders, Esq., an eminent button-manufacturer, for the purpose of lighting his manufactory, and also for soldering the shanks of buttons. It completely effected the objects for

which it was intended. In the same and the following year he erected several others on a similar plan for different individuals in Birmingham and its immediate neighbourhood. In 1808 he constructed and fixed an apparatus applicable to several uses for Mr. Benjamin Cook, a manufacturer of brass tubes, gilt toys, and other articles in which a great deal of soldering had to be done. This apparatus answered the purpose for which it was intended so well, that Mr. Cook furnished in Nicholson's Journal, vol. xxi., p. 291, and vol. xxii., p. 145, an account of it. He did not, however, name the person who had contrived and erected it for him. We think that "he who wins the palm should wear it," and would not, as faithful historians, deprive merit of its reward, although the person referred to, it would appear, was not quite so scrupulous on the point, having in 1810 received from the Society of Arts the silver medal for a drawing and description of Mr. Pemberton's apparatus.

In 1808 Mr. Murdoch communicated to the Royal Society an account of his having successfully employed coal gas to lighting up the extensive establishment of Messrs. Phillips and Lee, of Manchester; for which Count Rumford's gold medal was presented to him, and his paper was inserted in their Transactions, and thence copied into several periodicals, whence its contents were widely circulated. It contained much useful and accurate in-

formation, attracted considerable attention, and led to important consequences ; for it had a tendency to show by facts as well as by calculations, not the imaginary, but the real advantages attendant upon the use of gas. We find what Mr. Murdoch says in his subsequent statement very different, as to results, to what Mr. Winsor had but a short time before been telling the public in his secret results of his “ official experiments,” as he termed them ; for he says, “ Official experiments proved one chaldron of coal to contain 23*l.* 2*s.* in value, which gives about two hundred and forty-two millions for the yearly consumption of the realm. The estimated savings are only rated at 114,845,294*l.*, all costs of carbonizing, &c. deducted ; and if the *Company* only realize one-tenth of this reduced sum, each 5*l.* deposit will secure to the subscribers 570*l.* per annum. Wonderful as this may appear, the estimates and experiments will stand the test of the best calculators and chemists.” Another part of Mr. Winsor’s scheme was to *impose a tax upon coals*, in order to *promote* the use of his gas and coke ; this he calculated would produce a revenue of 10,751,000*l.* per annum to the Government. Mr. Murdoch, a practical man, holds forth no such prospects ; on the contrary, in plain and intelligible language, he says—

“ The whole of the rooms of the cotton-mill of Mr. Lee, at Manchester, which is, I believe, the

most extensive in the United Kingdom, as well as its counting-houses and store-rooms, and the adjacent dwelling-house of Mr. Lee, are lighted with gas from coal. The total quantity of light used during the hours of burning has been ascertained, by a comparison of shadows, to be about equal to the light which 2,500 mould candles of six to the pound would give; each of the candles with which the comparison was made consuming four-tenths of an ounce (175 grains) of tallow per hour.

“ The gas-burners are of two kinds; the one is upon the principle of the argand lamp, and resembles it in appearance; the other is a small curved tube with a conical end, having three circular apertures or perforations of about a thirtieth of an inch in diameter, one at the point of the cone and two lateral ones, through which the gas issues, forming three divergent jets of flame, somewhat like a *fleur-de-lis*. The shape and general appearance of this tube has procured it, among the workmen, the name of the cockspur burner.

“ The number of burners employed in all the buildings amounts to 271 argand and 653 cockspurs, each of the former giving a light equal to that of four candles of the description above mentioned, and each of the latter a light equal to two and a quarter of the same candles; making, therefore, the total of the gas-light a little more than equal to that of 2,500 candles, six to the pound. When thus regu-

lated, the whole of the above burners require an hourly supply of 1,250 cubic feet of the gas produced from cannel-coal; the superior quality and quantity of the gas produced from that material having given it a decided preference in this situation over every other coal, notwithstanding its higher price.

“ The time during which the gas-light is used may, upon an average of the whole year, be stated at least at two hours per day of twenty-four hours. In some mills, where there is over-work, it will be three hours; and in the few where night-work is still continued, nearly twelve hours. But taking two hours per day as the common average throughout the year, the consumption in Messrs. Phillips and Lee’s mill will be  $1,250 \times 2 = 2,500$  cubic feet of gas per day; to produce which seven hundredweight of cannel-coal is required in the retort. The price of the best Wigan cannel-coal (the sort used) is 1*s.* 1½*d.* per hundredweight (1*l.* 2*s.* 6*d.* per ton) delivered at the mill, or say about 8*s.* for the seven hundredweight. Multiplying by the number of working-days in the year (313), the annual consumption of coal will be 110 tons, and its cost 125*l.*

“ About one-third of the above quantity, or say forty tons of good common coal, value 10*s.* per ton, is required for fuel to heat the retorts, the annual amount of which is 20*l.*

“ The 110 tons of cannel-coal, when distilled,

produced about seventy tons of good coke, which is sold upon the spot at 1*s.* 4*d.* per cwt., and will therefore amount annually to the sum of 93*l.*

“ The quantity of tar produced from each ton of cannel-coal is from eleven to twelve ale gallons, making a total annual produce of about 1,250 ale gallons; which, not having been yet sold, it cannot yet be determined its value.

“ The interest of the capital expended in the necessary apparatus and buildings, together with what is considered as an ample allowance for wear and tear, is stated by Mr. Lee at about 550*l.* per annum, in which some allowance is made for this apparatus being made upon a scale adequate to the supply of a still greater quantity of light than he has occasion to make use of.

“ Mr. Lee is of opinion that the cost of attendance upon candles would be as much, if not more, than upon the gas apparatus; so that, in forming the comparison, nothing need be stated upon that score on either side.

“ The economical statement for one year then stands thus :—

	£.	s.	d.
Cost of 110 tons of cannel-coal -	125	0	0
Do. of 40 tons of common coal, to carbonize - - - - -	20	0	0
	<hr/>		
	145	0	0
Deduct the value of 70 tons of coke - - - - -	93	0	0
	<hr/>		
The annual expenditure in coal, after deducting the value of the coke, and without allowing any- thing for the tar, is therefore -	52	0	0
And the interest of capital sunk, and wear and tear of apparatus -	550	0	0
	<hr/>		

Making the total expense of the  
gas apparatus per annum about - 600 0 0

“That of candles to give the same light would be about 2,000*l.*: for, each candle consuming at the rate of four-tenths of an ounce of tallow per hour, the 2,500 candles burning, upon an average of the year, two hours per day, would, at 1*s.* per pound, the present price, amount to nearly the sum of money above mentioned.

“If the comparison were made upon an average of three hours per day, as in most cases would perhaps be nearer to the truth, and the wear and tear remaining nearly the same as in the former case, the

whole cost would not exceed 650*l.*, while that of the tallow would be 3,000*l.*”

From 1809 up to 1815 very considerable progress was made in the erection of works for manufacturing gas from coal in London and other places ; but about the middle of that year Mr. John Taylor, then of Stratford, in Essex, obtained a patent for an apparatus for the purpose of producing an inflammable air or olefiant gas, fit for yielding light of great brilliancy, and free from any disagreeable smell, from any kind of animal, vegetable, or mineral oil, fat, bitumen, or resin which can be rendered fluid by heat or otherwise.

Between the years 1815 and 1823 several companies were formed in different parts of Great Britain and Ireland, and also in other countries, for the purpose of making gas from oil or from the other materials named by Mr. Taylor in his patent ; and in consequence many such gas-works were built in towns where gas-light had not before been introduced, and in several in opposition to existing coal gas establishments. Such as were in favour of oil gas held out to the public many reasons why it should be preferred to gas obtained from coal.

1st. That the matter from which such gas is extracted does not contain any portion of sulphur ; therefore, that oil gas could be used with greater comfort in the house of the private consumer, and in many shops, particularly those of silversmiths,

cutlers, braziers, &c., in which they asserted, when coal gas was used, the goods were liable to tarnish, rust, &c. Its superior purity was also particularly dwelt upon: the most costly decorations were in no danger from its use; it left no offensive residuum whatever after combustion; was as cleanly as wax candles, but afforded a far more brilliant light.

2nd. That the lighting of cities and towns with oil gas would give great encouragement to the fisheries; and that in Ireland it would render incalculable advantages to the labouring poor (many of whom might be advantageously employed on the coast in the catching of sun-fish, &c.) whilst it would promote the farmer's interests by finding him a market for the offal fat, which was stated to be fully as useful as oil in the production of gas.

3rd. That as about three cubic feet in bulk of oil gas gave as much light as ten feet of coal gas, the expense of erecting the apparatus, &c. in the first instance was considerably diminished; and the expenses of carrying on an oil gas establishment, as far as related to labour and wear and tear, when compared with those for coal gas works, were very much reduced.

If we admit these statements to be correct, we still fall far short of the main point upon which any new branch of manufacture depends for success, viz., that the article manufactured shall be such as the manufacturer can afford to sell at a fair price to the

public, and such as will at the same time afford him a remunerating profit for the money he may have invested. In the case of oil gas, it so happened that neither of these ends were accomplished in any one instance; for the parties who used oil gas found it exceedingly expensive, whilst those who had invested their money in works and apparatus for generating and distributing oil gas, after several years' trial in many cases, and for a sufficiently lengthened period in all to see whether any profits would arise, found invariably that they had not the remotest chance of realizing any dividend worth naming by way of paying interest upon their investments.

Finding no profits arising from the manufacture of gas from oil, they had recourse to resin as a substitute; but that produced no better results as to profits than oil had done; from that the companies resorted, in the first instance, partially to the use of coal, and ultimately all the splendid establishments which had been built in the largest commercial and manufacturing towns of the empire for manufacturing gas from oil were converted into coal gas manufactories. Amongst the oil gas works more likely, from local circumstances, to have answered better than others, may be named those built in Liverpool, Bristol, and Hull; but in each of those places the companies, after lengthened and expensive trials, were glad to abandon the oil gas scheme altogether, and to reconstruct their respective works

so as to be able to procure gas from coal. In short, as oil gas, even when oil can be purchased at 20*l.* per ton, cannot be brought into the market to compete with coal gas; and as very great care is now taken to deprive the latter of all its impurities, coal gas is now, generally speaking, quite as innocuous as gas procured from oil can be.

In 1819, within the period of which we are now speaking, Mr. David Gordon obtained a patent for making vessels of great strength (fitted with peculiar valves to regulate the emission of the gas), into which it was proposed to compress the gas so as to render it *portable*. His inventions led to the formation of "*The London Portable Gas Company*," which for some time supplied various consumers with the *portable* gas; but that speculation, like the one upon gas procured from oil, failed, from its not affording any source of profit to the parties who had invested their money in works, machinery, apparatus, and the necessary carriages for carrying to their customers vessels filled with gas to supply their demand for that article.

Whilst the oil gas and portable gas companies were in existence, Professor Daniel, F.R.S., invented an apparatus for converting resin into gas; but that, like the two others, it would appear, had never any chance of competing with coal gas as a profitable speculation, though adopted by oil gas companies under a hope of realizing a profit.

As the manufacture of *oil gas*, of *resin gas*, and of *portable gas* has long ceased to be carried on by any gas company from the cause already named, and as it is more than probable such manufacture will not be again attempted, we do not propose to dwell further upon them, nor to load the following pages with descriptions of apparatus which could answer no useful purpose. We have spoken of them as warnings to deter others from running headlong into vast speculations without first endeavouring to establish, on a smaller scale, how far they promise to be profitable. It was remarked in a former edition of this work, that “in this age of improvement, we have almost daily brought before us inventions exhibiting much contrivance, which sometimes come forward with an importance appearing to the superficial observer as real, but which, when submitted to cool and sober investigation, leave us nothing to commend but the ingenuity of the inventor: for, whenever we have submitted to our consideration what is new in the practice of any art, we are, amongst other things, to establish not only its usefulness, but its economy also; and unless the invention be productive of the latter as well as of the former of these requisites, it must be set down, as far as it relates to the public good, of little intrinsic value, notwithstanding it may exhibit great marks of ingenuity and science.”

In 1823, when a strenuous effort was being made

to obtain an Act of Parliament for lighting Bristol with oil gas, the author of this work published a second edition thereof, in which was an entire chapter upon gas procured from oil: he did not then attempt to say anything to the disparagement of oil gas as a light, but, from his own practice, he furnished estimates of the expense of erecting a coal gas apparatus for generating gas for lighting 160 public and 500 private lights, to lay 7,500 yards of main pipe, &c., the expenses of carrying it on, and the annual receipts; by which it appeared that upon an outlay of 11,500*l.* the annual balance of profits would be 1,142*l.* 12*s.* 8*d.*, or very little short of ten per cent. per annum upon the capital invested. He also furnished similar details for an oil gas establishment of sufficient magnitude to supply an equal number of lights, and having the same extent of main pipe, the outlay for which amounted to but little more than three-fourths of that for coal gas, viz., 8,000*l.*; but when he came to set the annual expenditure (estimating the oil at something under 19*l.* per ton) against the annual receipts, he found that the former exceeded the latter in the sum of 124*l.*, so that the proprietors of such a company, instead of receiving any dividend at all upon the money they might have respectively invested, would have been at the year's end 124*l.* out of pocket. He also furnished a similar statement to the proprietor of the Monthly Magazine, in which publication it

appeared, during the time his work was in the press. What he then said upon the matter, subsequent experience has fully borne him out in, as the entire cessation of making gas from oil or from resin bears convincing testimony.

In the spring of 1823 the author made a series of experiments at the gas-works at Newry (Ireland), for the purpose of ascertaining whether gas could be procured from turf obtained from a bog about two miles distant from that town, which led him to conclude that, in places where turf was plentiful, it might be used advantageously instead of coals for procuring gas for lighting towns, &c. These experiments were made for the purpose of ascertaining whether a new source of industry could not be opened in Ireland by applying turf, which is in many parts of that country so abundant, to the purpose of making gas for illuminating purposes.

We have endeavoured to give a faithful account of the labours of those who entered into the field of gas-lighting during the very early stages of its existence, and having traced its progress from its birth up to a period when it was fast approaching towards maturity, we shall conclude our historical sketch; for, if we were to attempt to speak of all that has been achieved in improvements of gas apparatus, and to enter into statistical details (which, to furnish with any degree of accuracy for Great Britain and Ireland only, would require returns

stating the outlay, expenditure, receipts, and various other particulars as to quantity of light, &c. furnished from every gas establishment in the empire) as to the number and magnitude of the gas works which have been erected throughout this and other countries, within the last seventeen years, we should swell this chapter far beyond the bounds intended or the nature of the work would allow. We have shown many of the difficulties which the first manufacturers of gas for illuminating purposes had to overcome, and some of the prejudices they had to contend with, and in viewing these we can hardly fail of feeling surprise at what has been done in so short a period.

---

## CHAPTER V.

On the Retorts, and various Modes of setting them.

THE retorts used for the distillation of pit-coal are of different shapes in different establishments, being either circular, semicircular (or D shaped), elliptical, kidney formed, or square. It must be understood, that when adverting to their shape, a transverse vertical section parallel to the mouth-piece is spoken of. There was, however, a patent taken out in 1815 for a retort differing widely from any of the above—it was termed the “*rotary retort*,” but it was never brought into general use. We propose to speak of the different kinds of retorts as above named, but shall be more particular in our observations upon those now generally adopted, and such as seem most likely to answer the purpose of the manufacturer of gas.

The circular, or cylindrical, retorts have been tried under my own particular observation, under various modes of setting, during a lengthened period, so have been the D shaped and the elliptical, as were also the “*rotary retorts*,” so long as they were used at the Westminster Gas Works. I can, therefore, state such facts relative to each as I noticed myself, which

I expect will enable the gas manufacturer to form a just conception of the comparative value of the cylindrical to that of the D shaped, or the elliptical, &c. &c.; and having done so, I shall leave him to choose that shape which he thinks most likely to answer his purpose.

The circular, or cylindrical, retorts are from six to seven, or eight feet in length, and generally about twelve inches diameter inside. Those upon which my observations were principally made were only six feet in length, and were first set upon the flue plan and subsequently upon what is now generally called the oven plan. When set on the flue plan, and two heated by one fire, carbonization was carried on at about twenty per cent., that is to say, it required twenty tons of coals to keep a sufficient number of retorts so heated as to be capable of carbonizing 100 tons properly when the retorts were worked at eight hours charges with 160 pounds of coals to one retort for each charge.

When speaking of four, six, or eight hours charges, it is to be understood that so many hours elapse between the time of the coal being introduced into the retort and the coke being withdrawn from it, during which time the mouth-piece is closed by its lid, consequently the different products evolved must pass off through the connecting, H, and dip-pipes to the hydraulic main, and thence to their different reservoirs; the base of the coal, or coke,

being all that should be left in the retort when the lid is removed, preparatory to drawing out the coke.

The fire-place for heating the retorts I am now speaking of, set two over one fire, on the flue plan, was on that side of the brickwork opposite to their mouths; and, under these circumstances, a retort cast from iron of the second running, and weighing about ten hundred weight, would last from eight to ten months.

In tracing the steps which led towards the plans upon which retorts are very generally set, and comparing the advantages arising to the manufacturer by deviating from the plan of setting them as already described, we naturally suppose that any deviation therefrom would have in view the decreasing the per centage of carbonization, or the expenses attendant upon the wear and tear of retorts. In carrying out our inquiries we shall see how far either has been effected.

The first step towards the present mode of setting retorts was by heating three with one fire. On such plan several were set at different gas-works; and so long ago as the year 1817, I had an opportunity of making the most minute and particular observations from the time of their being set till they were entirely burnt out. The fire-places were in front of the retorts. By adopting that mode of setting the retorts, it was found in practice that it cost quite as

much to set a specific number on that plan as would set a like number on the flue plan with two over one fire. It was found also, that, instead of carbonization being carried on at a lower per centage, it was increased. The retorts I am now speaking of, and upon which my observations were made, did not heat uniformly: when the extreme end of them was almost at a white heat, that part which was within eighteen inches of the mouth-piece remained quite black. The coals were not well carbonized, consequently the proportion of gas procured from a ton diminished; and, to sum up the evils which resulted from that mode of setting retorts, the retorts were burnt out in about two-thirds of the time they had lasted when set on the flue plan, two over one fire. When all these things are considered, we shall not be surprised to learn that the three to one fire plan fell to the ground; for, from it expenses and inconveniences were increased, whilst there was a less return of products of all descriptions for meeting either.

Experiment on a large scale having proved that no desirable end was attained by setting three retorts to one fire, another mode was almost immediately tried, on which plan 100 retorts were put up at one of the London gas establishments. They were set four to one fire, but it was found impossible to bring them up to a good working heat; for one part of the retort would have required a heat suffi-

ciently strong to melt it before the other part had attained to even a dull red heat. A failure in one quarter did not prevent others from attempting to get over the difficulty. A second setting of retorts, in which four were to be heated by one fire, succeeded better than the first; for the retorts heated very regularly, but carbonization was not carried on at so low a per centage as when only two were heated by one fire; it was considerably increased, and, what was still worse, the retorts were sooner burnt out. The carbonization increased daily in its expenses, till at last it rose as high as fifty per cent. This was principally owing to fewer retorts being worked than the fires necessary to be kept up would have heated, had the retorts placed over each fire that was kept lighted continued in a working condition. It very frequently happened, that when seventy or eighty retorts only were at work, as many fires were kept lighted as actually heated 100, from the cause we are about to mention. The action of the fire not being uniformly directed towards each retort in the series of four, one of them frequently became burnt through, and was consequently ineffective; whenever such was the case, only three out of the four could be used for making gas; soon afterwards a second would give way, and then but two remained in use, and so on. Indeed, it was no uncommon occurrence to work but two retorts by means of that fire which was capable of

heating four, from two out of the four being burnt out. This was a matter of necessity; for, whenever it became necessary to remove defective retorts over one fire in order that they might be replaced by such as were effective, the adjoining fires could not be kept lighted; for, if they remained so, the brick-setters could not perform their work owing to the heated state of the brick-work; consequently, when it became necessary to replace a series of four, the use of twelve retorts was lost to the manufacturer till such time as the defective ones over the fire-place undergoing repair were removed and replaced by new ones, and the brick-work all made good preparatory to their being again brought into action. The pulling down of the defective retorts and the replacing of a series of four, so as to be again ready for working, was seldom accomplished in less than a week; therefore, when the manufacturer was unable, from the quantity of gas he had to supply, to dispense with the use of so many retorts, he was compelled to work them under every disadvantage.

When retorts were set four to one fire the top ones invariably failed first, and this led to a supposition that if the top ones were guarded by fire-tiles from the action of the flame, in the same way that the lower retorts were guarded, they would probably remain for a longer time effective. Retorts were accordingly so set, and whilst the fire-places were continued at the side of the retort bed oppo-

site to that for charging and drawing the retorts, they did last considerably longer; but they were by no means so effective as on the former plan. They collapsed and fell out of all shape, and in consequence could not contain such a quantity of coals as could be profitably carbonized by the coal-gas manufacturer. A deviation from this mode was made by placing the fires in front of the retorts, but it was a complete failure. The bottom retorts were soon destroyed, the flame from the fire-place playing so forcibly upon their ends as literally to reduce them into a state of fusion, although the flame was such as only to keep the principal part of the retort at a bright red heat.

Although retorts of various shapes had been used at different gas establishments prior to the year 1817, we find no account of any having been set save on the flue plan, that is, by the fire acting under the retort and then returning over it on its way to the main flue, till the spring of that year, when a plan was adopted for heating cylindrical retorts set in ovens, a plan then denominated the "*oven plan*;" it still bears the same name, but since its first adoption has been very greatly modified and improved. The first experiments were made at one of the London gas-light establishments, by heating one retort in an oven. It was reported to have heated uniformly and at little expense. At the same establishment were next set two in one oven, then three,

and afterwards five. It may be observed here, that retorts of almost every shape on different modifications of the oven plan, each oven containing five, seven, and in some cases a greater number of retorts, are now generally so set at gas-light establishments. Of the cylindrical retorts set in ovens in the year 1817, I had only an opportunity of making my observations upon twenty. They were set in four ovens, each oven being heated by three fires; consequently, when all the retorts were serviceable, twelve fires were required to be kept up to heat twenty retorts. By the adoption of the oven plan, as it was then arranged, hardly any advantages could have been expected to be gained; on the contrary, it was demonstrated that the destruction of the retorts was more rapid than when set on the flue plan, owing to the lower ones being placed immediately over the fire, from the action of which nothing whatever was placed to guard them. The form of the retorts precluded every hope of carbonization being accomplished in less time than by any others of a cylindrical shape; and as to the per centage at which carbonization might be carried on, what could be expected favourable when, after the retorts (upon which my observations were made) had been in action six weeks only, it was necessary to keep up twelve fires to enable the stokers to work twelve retorts?

The rapid destruction of the retorts when set on

the oven plan immediately over the fire-places, and without any protection from the action of the fire, induced persons connected with gas manufactories to turn their attention to the matter, so that the retorts might be kept at a proper temperature by reverberated heat and yet be so protected as not to be rapidly destroyed, as had been the case in the plan just spoken of. The first step towards using the reverberatory furnace successfully, as applied to the heating of retorts, was by having the fire-places covered with fire-tiles or fire-humps, leaving occasional openings at the sides for the flame to pass through into the retort oven, by which the brick-work became properly heated, as did also the retorts. In ovens where five retorts were used, the three lower ones rested upon the fire-tiles which covered the fire-places, and the two upper ones were supported by means of pillars built of fire-bricks. To protect the lower retorts from the action of the flame which arose through the side openings, the retort oven was made sufficiently wide to allow the two outer bottom retorts to be cased with fire-bricks made for the purpose, by which means a retort would continue serviceable nearly double the time it would have done without such protection; for when the retorts were left altogether unprotected from the action of the fire, they were very rapidly destroyed, and were quite as soon rendered unserviceable if the retorts were left unprotected where the

side openings were placed, and more particularly so if the retorts projected over a part of them. When such was the case, the retorts would have holes burnt through them opposite to each of the side openings, by which they were rendered useless in less than one half the time in which they would have been so had they been properly protected.

Upon a plan nearly similar to what we have been describing, cylindrical, ellipsoidal, kidney-formed, and D-shaped retorts continued to be set for some years subsequent to 1818. In that way elliptical retorts were set in several gas works, and were found to last for more than two years, though kept constantly in use, when set in nests or ovens of five and heated by two fires. In some instances, under this improved arrangement, carbonization was said to have been carried on at less than thirteen per cent. The improvement was not, however, universally adopted; many other modes were tried, several of which led to a more rapid destruction of the retort than had been the case when the flue plan was followed, and consequently to increased expenses.

With cylindrical retorts, the manufacturer cannot expect, by one mode of setting more than another (provided the retorts can be kept at a good working heat), to obtain a greater proportion of gas from a given quantity of coal, and that in a shorter time; for, whenever coal may be submitted to distillation in masses of twelve inches diameter, the operation

will be very tedious and equally imperfect. The heat passing through, and from the red hot retort acting upon the outer surface of the coal within it, will cause that outer surface to be speedily decomposed, consequently the gas generated will pass off very rapidly during the first hour of the charge in particular, during which hour one-fifth of the entire quantity of gas the charge of coal contains will be extracted, about three-fourths of the quantity made during the first hour will be generated during the second hour of the process, and about seven-tenths of that amount during the third; so that nearly one half of the entire quantity of gas that can be obtained from the coal within the retort will be obtained during the first three hours of the distillatory process. The reason of this is easily explained; the outer surface of the coal is first acted upon by the heat, and, as that is the largest surface, it presents the greatest surface of coal to be decomposed, and consequently admits of a greater quantity of gas being thence extracted; but, so fast as the gaseous and other matters are generated, it becomes more compact and forms itself into a crust of hard and compact coke of some thickness, which counteracts to a certain extent the process in the interior part of the cylinder formed by the coal inside of the retort; for the core of the charge is deprived of much of the heat of the fire by this outer case of compact coke, and the gas thence evolved must force its way through the same

before it can extricate itself from the retort. Whenever such is the case, carbonization cannot be carried on to advantage, nor will it answer any one desirable end. The great object which the manufacturer should ever keep in view, is to obtain the greatest quantity of gas in the least time and at the least expense; such can never be effected by means of cylindrical retorts or by means of retorts of any other shape into which the coal is of necessity introduced in masses of considerable thickness: his plan, therefore, must be to use retorts of such shape as will admit of the coals proposed to be carbonized being spread out in layers of from three to four inches in thickness. For such mode of operation the elliptical retort twenty inches by ten inches inside, kidney-shaped twenty inches by ten inches inside, or the D-shaped, with the straight part representing its bottom, twenty inches in width and ten inches in height inside: a convenient length for any of the retorts just named is from seven feet to seven feet six inches. With any of the above shaped retorts, 120 pounds of any of the descriptions of Newcastle coals will be well carbonized in from four to five hours.

Before speaking of the more recent improvements in the mode of setting and working retorts, we shall say something relative to the "*rotary retort*," which we are induced to do from the action of that retort bearing us out in what we have remarked

relative to submitting coal in thin layers to the distillatory process. We first remark that Mr. Maiben, of Perth, invented a retort for distilling coal by exposing it to the action of heat in thin strata. From his experience he learnt that the gas evolved during the first part of the process of carbonization was of too aqueous a quality to be fit for combustion, and that evolved during the latter part of the process was so strongly impregnated with sulphur as to be highly objectionable. To remedy those evils, he considered that, if the coal were spread in a thin layer in the retort, the action of the heat thereupon would be more instantaneous; consequently, the bad gas evolved in the beginning and towards the end of the process might by means of a valve be prevented from entering into the gas-holder. The retorts he made use of were of a square shape, and of a size sufficient to carbonize twenty-five pounds of coal when spread out therein in a layer of about two inches thick. The coal was introduced into the retort by means of a sheet iron box, which was charged and slided in whenever the gas had been extracted from the former charge, which, under such management, was generally accomplished in two hours. This description of retort being much too small to be serviceable in large establishments, led Mr. Clegg to construct a retort on similar principles, and of sufficient capacity for carbonizing about twenty-seven hundred-weight of coals in twenty-

four hours. For this retort he took out a patent in December, 1816; and in the *Repertory of Arts* for that month, No. 175, and for January, 1817, No. 176, a particular description of the invention is to be found. The first of them which was ever put up (being eight feet six inches in diameter), as were also the second and third (each of twelve feet six inches diameter), were worked under my observation from the time they were first brought into action, a period of several months, till they were taken down to make room for a new retort-house which was required to be built by the company. Each of these retorts contained fifteen boxes, made of strong boiler plate, riveted together, which slid into the retort upon wrought iron arms, as described in the specification published in the *Repertory of Arts* above alluded to. Whilst the arms could be kept up they were worked without much difficulty. The coal remained in the retort six hours, but was only exposed to the action of a red heat one-third of that time, or two hours. Five boxes, having passed that, waited in the retort for the coal in the five boxes over the red heat being decomposed, which, on being effected, the retort was opened, and those five boxes which had passed the red heat were withdrawn from the retort and fresh ones charged with coal introduced upon the arms they had occupied. This process brought the five boxes which had been over the red heat into the situation which those just drawn had

lately occupied, there to remain till the coal in the five just brought over the red heat might be decomposed when the operation of change was again, as already described, repeated; so that there were continually five boxes charged with coal lately introduced into the retort, gradually drying prior to being brought over the red heat—five filled with well dried coals over the red heat, and five others filled with coke produced from the coal they contained whilst over the red heat, ready for being withdrawn from the retort. Had not the expense of erecting retorts of this description been very considerable, and the wear and tear enormous, they would in all probability have been adopted in that establishment where they were first tried; but both were so much against them, that every idea of using them there was abandoned. It is but justice to state that the “*rotary retorts*” produced gas at the rate of upwards of 11,000 cubic feet from one ton of coals, which was full fifty per cent. more than what were reckoned at that time very good results from cylindrical retorts, 7,400 cubic feet of gas from one ton of coals being the maximum. I am now speaking of results in 1817 and 1818, which the reader must bear in mind; for, from one step to another the quantity of gas obtained from a ton of coals has gradually increased to about 9,000 cubic feet, although 8,500 has been set down by Mr. Joseph Hedley as the London average in 1837. Under

some recent patented improvements in gas apparatus, I have, during the year 1840, been obtaining at an average upwards of 12,000 cubic feet of gas from a ton of Townley Main and other Newcastle coals, which apparatus and the results therefrom I propose hereafter to describe ; I shall not, therefore, dwell further upon either here, but return to the *rotary retort*, by means of which carbonization was carried on at from sixteen to eighteen per cent. The increase of coke on coal carbonized was about fifty per cent., and the process of carbonizing under the above circumstances was accomplished in about six hours. During the time the *rotary retorts* were in action, I had abundant opportunity for observing that the statement of Mr. Maiben, which had appeared so reasonable, was fully verified in practice, even on a large scale ; and from thence learnt that the more rapidly the decomposition of coal is effected, exactly in the same ratio we are to expect an increase in the quantity of gas generated from a given quantity of coal ; for when cylindrical retorts, charged with Bewicke and Craster's Wallsend coals, worked at a low temperature, and at six hours charges, were producing but from 6,000 to 6,700 cubic feet of gas from one ton of coals, the *rotary retorts* were producing from 11,100 to 11,850 cubic feet of gas from the same quantity of coal ; three-fourths of which was evolved in one-third of that time, or in two hours.

The distillation of coal when exposed in thin strata to the action of the fire having been proved by very extensive experience to be the most beneficial to the manufacturer, as far as relates to the products obtained; therefore, if the expenses of setting retorts proper for such a process, and keeping them in repair, could have been accomplished at anything near the sum requisite for working those of cylindrical form, it was but natural to expect to see some mode adopted likely to produce the effect sought for. Mr. Maiben's retorts were much too small for extensive manufactories, and the *rotary retorts* were so very expensive, it was not probable that either could be brought into general use. To overcome the difficulties arising from the use of retorts such as I have just mentioned, it was proposed to use ellipsoidal retorts about six feet six inches in length, their major axis being twenty inches, and their minor axis ten inches inside dimensions. From retorts of this shape there was every probability that the results, as far as related to the quantity of gas and coke obtained from a ton of coals, would be very similar to those from the rotary retort; whilst the expense of setting them would be but little more than what was incurred by setting an equal number of cylindrical retorts, and not near so much as the cost of setting that number of cylindrical retorts which was capable of carbonizing equal quantities of coals in equal times. Upwards of twenty years of

extensive experience have fully demonstrated this to me. The elliptical retorts, the kidney-formed, or the large D retorts have great advantages over cylindrical ones. The charge in them may be worked off in half the time that it can be in cylindrical retorts; and five of them in action, worked with 120 pounds of coals to each, during a four hours' charge, will produce as much gas in twenty-four hours as ten cylindrical retorts, worked at eight hours' charges, with 160 pounds of coal to each retort every charge. The elliptical retorts on which my observations have been made have generally been set in these various ways, viz.: two to one fire, on the furnace plan; three in one oven, heated by means of a furnace; five in one oven, heated by a furnace; three in an oven, and five in an oven, each series being heated by means of coke-ovens. The elliptical retorts on which my first observations were made were set five in an oven, and were heated by one fire. They were taken down after being ninety-four days in action (to make room for some alterations of buildings in the manufactory), so little injured by the fire that two out of the five were but barely discoloured, and the remaining three had not at all fallen out of shape. At the very time that those retorts were in action, cylindrical retorts set on the oven plan were almost always entirely burnt out in less than two months.

Having spoken of the cylindrical, rotary, and el-

liptical retorts, I shall make a few observations upon the semi-circular, or D-shaped, the kidney-formed, and the square ones, preparatory to describing several methods of setting retorts, as hereafter illustrated by the plates. The semi-circular, or small D retort, from its form, when set with judgment, is applicable to small gas establishments, being easy to charge and draw ; the lid of the mouth-piece being much lighter and more easily taken off, luted, and refixed than that of the larger D retort, of the elliptical, or of the kidney-shaped. It is not, however, so well adapted for producing the best results as to quantity of gas obtained as any of the above-named ; for if 160 pounds of coal be introduced into a small D retort, twelve inches across the bottom and twelve inches in height, inside dimensions, and length about seven feet, it will nearly fill it ; hence the same objections to the use of it hold good, as have been urged against the cylindrical retort of about the same size. I have had abundant opportunities during the last ten years of noticing the results from small sized D retorts, and am prepared to say that the average quantity of gas from Felling Main and other Newcastle coals did not exceed 7,800 cubic feet of gas to the ton. They were set in ovens of three, two, and one nearly similar to the oven of three D retorts, as shown in one of the plates, the oven of two being the same width as that of three, but with an elliptical arch over it, and the

oven of one being rather more than half the width of either of the other two.—The retorts were so set that the proprietor for whom they were erected might use one, two, three, four, five, or six, or any greater number, as the nights gradually became longer, or, contrariwise, leave off the use of one, two, three, &c., as the nights became shorter—an arrangement found advantageous in a small town where, during two of the summer months, one such retort was found sufficient to supply the quantity of gas which was called for by the shop-keepers and other private consumers. In most small towns such an arrangement of retorts, whether they be D-shaped or otherwise, is better, supposing six retorts require to be put up, than fixing them in two ovens of three each; that is to say, an oven of three, an oven of two, and an oven of one retort. At the places where the small D retorts as above were fixed there was not any great demand for coke; in consequence, that product was used as fuel for heating the retorts, and therewith carbonization was carried on at an average of about thirty per cent. upon the cost of the coals used for making gas. At one of the establishments, where nine D retorts were put up, a period of more than two years elapsed before even one of them required to be replaced, though the *net* annual income to the proprietors exceeded 500*l.*; and at another, of about the same magnitude, the results as to the per centage at

which carbonization was carried on, and the wear and tear of retorts were nearly similar to those which have been just stated.

In some instances, D retorts have been set six in a range, nearly similar to the square retorts (see Plate VII., figures 4 and 5); but, instead of being heated by a furnace, a coke oven was employed for that purpose. That mode of setting has, however, nearly gone out of use, and retorts so set are not to be found now at many gas-light establishments.

The semi-cylindrical, or large D retort, with its horizontal diameter from twenty to twenty-two inches, and its vertical varying from nine inches to twelve inches, inside dimensions and length, exclusive of its mouth-piece, from seven feet six inches to eight feet, is probably as good a shape for producing high results as to gas obtained as any that can be used; for in it 160 pounds of coal can be spread over the bottom in an uniform layer of between three and four inches in thickness; when so, if the retort be kept at a bright-red heat, a charge of 160 pounds will be completely worked off in about four hours, so that one such retort will carbonize, in twenty-four hours, about 960 pounds of coal, and produce nearly 4,000 cubic feet of gas from almost any of the Newcastle unscreened coals. In practice I should recommend, in works where more than six retorts are required, that large D retorts should be set in ovens, with three retorts in each, as here-

after described, with descending flues, where such arrangement is practicable ; but, in those instances where recent improvements may be adopted, and from which we may expect to get 5,000 cubic feet of gas from the same retort, the same quantity of coals and in the like time, the descending flues cannot be adopted.

The kidney-formed retorts possess very nearly the same properties as the large D-shaped and elliptical retorts—these may be set singly, in twos, threes, or fives, as may be most convenient, and either over furnaces or coke-ovens. Indeed any of the descriptions of retorts may be heated by means of coke-ovens, if in the place where they are used there is a ready demand for coke, either for malting or other purposes. The coke produced in the coke-oven, as it is generally constructed, when applied to the purpose of heating the retorts in a gas manufactory, is quite as good for malting as that which the maltster prepares in ovens which he constructs for the express purpose of making coke. Such coke is also well adapted for the use of the iron-founder, and when made in ovens sufficiently large for heating three or five elliptical or large D-shaped retorts, if such ovens be properly managed, the coke will answer his purpose quite as well as if prepared in the ordinary manner. Where, therefore, there happens to be a demand for coke, the gas manufacturer will consult his own interest by using coke-

ovens for heating his retorts, as by so doing, the coke produced, from the coal from which the gas is extracted and from the coke-oven, will more than pay for all the coal he may use for both purposes. But, if he cannot find a market for his coke, then it will be to his interest to heat his retort-ovens by means of furnaces arched over as hereafter shown in our description of the different kinds of retorts and the modes of setting them. The furnace system possesses one very material advantage over the coke-oven mode of operating; for, should circumstances require the retorts to be worked at a higher temperature than usual, for hastening the distillatory process, or for procuring more gas in a shorter time, it would be found by the coke-oven plan very difficult, if not impossible, to effect either purpose; but either might with ease be accomplished by means of furnaces, so that whenever any contingent call for an extra supply of gas may be expected, it would in such case always be the wisest plan to have all the retorts heated by furnaces, or, at all events, such a number as would meet any extraordinary demand for gas called for at a short notice.

The so-called square retort is generally about twenty inches in breadth, thirteen inches high, and six feet long inside. It has a rib cast along the middle, on the inside of that part which is the bottom when the retort is set. This rib rises to the height of

three inches, but does not approach nearer to the mouth-piece than about eighteen inches. It is for the purpose of strengthening the bottom of the retort and preventing it from falling out of shape ; but when we consider the mode in which square retorts are set, that is to say, side by side, with the bottom of each resting upon a flat surface of fire-humps or fire-tiles, (see mode of setting square retorts in plates,) it does not appear to be necessary. These retorts, when set six in one bed, and that number heated by one fire, are placed close alongside of each other. The fire is at one end of the range, and is so contrived as to admit of the flue being carried under the whole range towards the mouths of the retorts ; it is then brought over the top of them, and again under and over in the like way, previous to its being allowed to enter into the main flue. Under this arrangement, square retorts, weighing about thirteen cwt., being worked at six hours' charges with 120 pounds of coals to each as one charge at such a heat as causes 7,500 cubic feet of gas to be generated from one ton of the best description of Newcastle coals, are found to remain serviceable one year. The carbonization (when they are once brought to a working state) is carried on at about twenty-five per cent. ; but they require good fires to be kept up under them for a fortnight or three weeks before they attain to a proper working heat. These retorts are not so advantageously used

as others we have been speaking of. They are more expensive in the first instance than cylindrical retorts. The length of the flues passing under and over them being extensive and of but small dimensions, they are frequently choked up, and require, for clearing them out, various openings. When, therefore, it is found necessary to examine those flues, it generally happens that the heat of the retorts becomes very considerably decreased; and, when we consider the time requisite for heating them in the first instance, we must be aware that such a diminution cannot be overcome but by a considerable expense of fuel, and by carrying on the process very unfavourably and imperfectly. Lastly, when the retort is burnt out, the cost of replacing it is nearly equal to the first cost of setting it; whilst in using cylindrical, elliptical, D, or kidney-formed retorts set in ovens, a retort is generally replaced for about one-half of the expense of its first setting; for the arches over the ovens which contain the retorts, if well constructed in the first instance, will remain serviceable for many years (several which have been up under my direction have been in use for upwards of ten years, and are still nearly as good as when first erected); and when retorts so set are burnt out, all that is required to be done is to remove the brick-work in front from the soffit of the arch to the level of the furnace bars should they be heated by furnaces; or to the crown of the arch of the coke-oven should

they be heated by means of coke-ovens; and then draw out the burnt-out retorts by means of proper tackle. When the defective retorts are removed, the bricklayer can repair the furnace, which, in twelve months, if constantly in use, will be very much burnt away, and turn the arch over it, upon which the lower retorts will have to rest preparatory to new ones being fixed. In such a case, a bricklayer and labourer will be able to repair a furnace for three or five elliptical or other large retorts in a couple of days, provided they be not delayed by waiting for the effective retorts being fixed. Where a coke-oven is used, supposing the arch over it be not injured, and which it will not be for several years if turned with fire-bricks made for the purpose (brick and brick) laid end wise, the work of the bricklayer and his labourer for replacing five burnt-out retorts will not exceed one day.

As on the proper mode of setting the retorts the prosperity of a gas-light establishment mainly depends, I trust the reader will not think me tedious if in this place I furnish my own views upon the subject. By mode of setting, I mean, first, that the furnaces or coke-ovens should be so constructed as to ensure at all times a sufficient quantity of heat for raising the retorts to such a temperature as will thoroughly decompose the coal submitted to distillation in a period of from four to six hours, when charges of from 120 to 160 pounds of coals are used

in each retort for one charge. I am now speaking of elliptical or other retorts which admit of the coals being spread over a large surface in thin layers. Secondly. That where furnaces are used, the expense of fuel should be as low as possible. In my own practice, taking the average of five-and-twenty years, I am prepared to say, the average quantity of coke or coal used as fuel for heating the retorts has not amounted to thirty per cent. on the cost of coals used in the retorts for making gas. On the coke-oven system, as has been before observed, where there is a quick sale for the coke, the coke produced sells for more than the coals cost. There is another point beyond those already noticed, which is well worthy of attention,—it is, that the brick-work which surrounds the furnaces, coke-ovens, and retort-ovens should be well executed. My attention has been drawn to this matter from finding it is the practice with some of the retort setters of the present day to use no lime mortar in any part of their work, whereas in several parts of it such mortar is very preferable to fire-clay. Where fire-clay is used altogether, it will much increase the expense of setting the retorts in the first instance; and having no bond, will, particularly in the filling up between the arches over the retort-ovens, and in the covering over the upper flues, &c., be apt to crack and give way, so much so, that, by the time the retorts are destroyed, it will be necessary to

take down and rebuild anew the entire of the work, thus entailing an immense and altogether unnecessary annual expense, an expense which might be saved if all the parts which did not come into immediate contact with the fire were laid in lime and sand-mortar, and all the joints well filled in every course with grout of a similar description. If the work were so done, and fire-bricks were used for turning the different arches made expressly from models to suit the spring and sweep of the arch, so that when placed upon the centres they lay brick and brick so as not to admit of any fire-clay between them (except a very thin grout poured over the arch when turned to fill up any small interstices), and if the fire-bricks of the furnaces and coke ovens were so laid also, though even the first cost of erection might be rather more than by a more unworkman-like mode of procedure, still in the end the manufacturer would find by adopting it a very considerable annual saving therefrom.

Another matter in the working of retorts is of some moment; that is to say, there ought to be every facility afforded for drawing and re-charging them; for when the lid is removed from the retort and the coke therein is withdrawn, the action of the air upon the metal is apt to cool it before the coals of the fresh charge can be thrown in in the ordinary way. To remedy this evil at many of the large gas-works, the coals are now introduced by means

of a long tray or scoop, into which the proper quantity of coals has been put. This scoop, so charged with coal, is introduced into the retort, and then turned over and withdrawn, leaving the coal uniformly spread over the bottom, and thus allowing the lid to be replaced much sooner than it could be supposing the charge had to be thrown into the retort by means of a shovel. In very small works, however, it cannot be adopted, as it requires more than one man to manage the scoop or tray plan properly.

Whilst speaking of the retorts and making such suggestions relative to setting and working them, it may not be out of place if we remark that the great expense of heating them led some persons engaged in the erection of gas-works, so early as the year 1819, to consider whether it was not possible to adopt a system which would effectually answer the purpose of heating retorts without that waste of fuel which must ever arise when they are heated by means of furnaces or fire-places, and it was then considered practicable to obtain that end by making a coke-oven for heating each nest, or batch of retorts, provided the heat generated during the carbonizing process could be applied so as to act upon the retorts. This end has been fully attained, and the consequence resulting from the use of coke-ovens is, that the coal which is used under such circumstances (instead of being destroyed after performing

the heating process) is drawn from the oven in the shape of a very valuable coke, equal in weight, at an average, to one half of the weight of the coal used ; and where there are iron foundries or malting establishments at hand to create a market, this coke is of equal value to the coal which produced it, so that the manufacturer heats his retorts for nothing, instead of incurring an expense of from twenty-five to thirty per cent. on the coals used for the production of gas. This is all well when a market can be found ; but in places where there are neither founders nor maltsters to take the coke so made, it becomes a very expensive and wasteful process : it therefore behoves all gas companies to satisfy themselves whether, if they should adopt the coke-oven plan for heating retorts, they can find a market for their coke. The coke thus made is not of a quality fit for ordinary purposes ; and hence some concerns where the coking system has been followed have been overstocked with coke to an enormous extent. By placing a set of grate-bars, however, opposite the coke-oven door, and making an ash-pit below, which can be closed by a door made to fit air-tight (see mode of converting a coke-oven into a furnace in plate, and as described at the end of this Chapter), a coke-oven may be worked as a furnace in a case of emergency, or when the stock of coke on hand is increasing. When used as a coke-oven, the door of the ash-pit is kept shut so as to exclude any draught

of air from passing through the fire-bars ; but when as a furnace, it is kept open, and the coal or coke used for heating the retorts thrown in so as to occupy very little space beyond the range of the fire-bars on the bottom of the oven. It will easily be understood that the coke made in this oven will be precisely similar as to quality to that made in an oven without grate-bars, and it will as easily be comprehended that it possesses the advantages which the furnace-system offers.

Before we commence describing the different modes of setting retorts, as exhibited in the plates herewith furnished, we may make a few remarks upon some of the descriptions of retorts which have from time to time attracted the attention of gas companies, but which, generally speaking, are either entirely out of use or only to be found in few places, and these in a comparatively small way. At one time we had retorts made of fire-humps, fire-bricks, and fire-clay, very large, heated at great expense, and, in spite of the greatest care and skill, soon becoming leaky. At another time we had fire-clay retorts round and elliptical, and of other shapes, moulded of the shape required before being burnt : these were thought likely to be very durable, and also to produce very extraordinary results ; but on being tried, they were found neither to possess durability nor to offer any other advantage over cast-iron retorts of the same shape and size. We

have had and still have retorts which feed and discharge themselves, and others again of as many forms, descriptions, and sizes, as would take a volume to describe, instead of a page or so, which is all the consideration of the subject as to practical utility requires. Retorts upon retorts have been patented or laid before the public through the medium of the periodical press; some ingenious and clever, others stupidly absurd. It has been our constant endeavour, amidst such an abundant supply of materials, not to mislead or bewilder our readers by noticing absurdities or by prolix details, and therefore we do not propose to select from patented inventions (unless in cases of obvious utility and confirmed merit) any apparatus, whether it be retort, condenser, purifier, gasometer, or anything else used by the gas manufacturer. We shall content ourselves with describing such apparatus as we think most likely to answer the manufacturer's purpose, and we trust that in doing so we shall make ourselves perfectly intelligible.

Having made these remarks, we shall next describe the *method of setting two cylindrical retorts on the flue plan, so as to be heated by one fire, as exhibited in Plate VII., figures 1, 2, and 3.* *Figure 1* exhibits a longitudinal section of these retorts. In it *a* is the fire-place, *b* a section of the fire-bars, and *c* the ash-pit. The direction taken by the flue is pointed out by small arrows.

*Figure 2* represents a front view of two cylindrical retorts set to one fire on the flue plan. In it the manner in which the conducting pipes are connected to the retorts is exhibited: these lead to the hydraulic main in a similar way to what is shown in Plate X., figures 1 and 2.

*Figure 3* is a vertical section of the same retorts, supposed to be drawn about midway of their lengths. In this section *a* represents the end of that part of the flue leading from the fire under the lower retort which rises near the mouth-piece thereof through the openings *b b*, and passing between the two retorts, rises over the end of the upper one; and being brought over the top of it, by means of an opening *c*, about nine inches from the mouth-piece, enters the upper flue, and thence passes into the main flue. *ddd* are vertical sections of the fire-tiles; on the bottom and middle one the retorts are supported, and the upper one forms the bottom of the top flue.

*Description of the method of setting six square retorts so as to be heated by one fire, as exhibited in Plate VII., figures 4 and 5.*

*Figure 4* represents a transverse section of square retorts, in which six are heated by one fire. These retorts are twelve inches square inside, and six feet in length. The fire-place *a* with the ash-pit *b* is placed at one end of the series; but so as when the observer stands in front of the retorts he shall be in

front of the fire-place also. Under this arrangement the retorts 1 and 6 heat the best, and 5 the worst. If the reader compares the situation of the flues, as exhibited in figure 5 of this plate, he will observe that there are four which communicate with the fire-place. These are divided by fire-humps laid edgewise across the whole series of retorts, forming the flues marked *dddd*, figure 5. This range of flues is covered by fire-tiles, and upon them the retorts are placed close alongside of each other. Over the top of the retorts is a range of flues *eeee*, which corresponds with the lower ones, and these are covered with fire-tiles and a course of fire-bricks. Upon the latter is a third series of flues of about two-thirds the depth of the former ones, and these rise by the opening *f*, figure 5, into the main flue. In figure 4 the transverse direction of the flues is shown by the arrows leading from the fire-place. The mouth-pieces of these retorts are circular, as shown upon the retort marked 6.

*Figure 5* represents a longitudinal section of these retorts, in which the flues and action of the fire have already been described. *A* is the retort, *a* the fire-place, *b* the ash-pit, and *c* the fire-bars.

*Figure 6.* Five elliptical retorts heated by two coke-ovens, exhibiting front view of one oven of retorts, and transverse vertical section of another. 1, 2, 3, 4, 5, retorts. *a*, door and frame to coke-oven A. *b*, opening to coke-oven B, without showing

door and frame. C, a cast-iron plate, with a rib along the back of it, built into the brick-work, to prevent the pushing out of the arch E (figure 7) over the coke-oven. The ends of the plate C fall behind the upright cast-iron pilasters D D, which are secured in their places by means of screw-bolts passing entirely through the brick-work, with a boss and nut at the back and nuts in front, as shown at *cc*. \* \* \* \* \*, situation of sight-holes for examining the heats of the retorts, and for removing any deposit which may accumulate. A, transverse vertical section of one of the ovens. B, transverse vertical section of the other oven. *eeee*, height at which the arches E E E spring. E E E, section of the arch E (figure 7). F F F, section of the fire-blocks. F (figure 7), upon which the retorts 1, 2, 3 are laid. G G, pillars built of fire-brick (see also figure 7), upon which the shields H H rest, for guarding the two upper retorts 4 and 5. The shields are made to pattern by the fire-brick manufacturer. The flues and the direction the flame takes on its way to the main flue are both marked by arrows, and more fully explained by figures 7 and 8. I, arch of fire-bricks over the retort-oven.

*Figure 7.* Longitudinal section of figure 6, in which the corresponding parts are marked with similar letters and figures of reference.

*Figure 8.* Plan of the flues above the arch I (figures 6 and 7) which lead to the main flue.

*Figure 9.* Plan of the under side of the arch I (figure 6), the situation of the front and back vents to the flues, and the situation and dimensions of the side flues \* \* \* \*.

Figures 6, 7, 8, and 9, are drawn from a scale of a quarter of an inch to a foot.

*Figure 10.* Front view of sight-hole frame and lid.

*Figure 11.* Section of sight-hole frame and lid.

Figures 10 and 11 are drawn from a scale of one inch and a half to a foot.

*Plate VIII., Figure 1.* Front elevation of one retort with its connecting pipe, and sections of two others similarly set; each heated by one furnace, drawn to a scale of a quarter of an inch to a foot. Figures 2, 3, and 4 are also drawn to the same scale. A A A, arches turned over the ovens in which the retorts are placed. B B, sections of retort-ovens. C C, transverse vertical sections of the retorts. C \*, front elevation of retort, showing flange and upright connecting piece. D D, vertical section of arches over the furnaces, upon the crown of which the retorts are placed. \* \* \* \*, openings in arches D D for allowing the flame from the furnaces E E to rise into the retort-ovens B B (see also figure 3, in which the corresponding openings are similarly marked). a a a a, casing of fire-tiles to prevent the flame from the furnaces striking upon or against the retorts, so that they may be heated by reverberation only. F F, sight-hole covers,

which can be removed, for ascertaining the heat of the retorts, or for clearing away any deposit which may accumulate in the retort-ovens. *b*, opening in the top of the retort-oven leading into the flue *c*, which proceeds towards the main flue *d*. *G*, furnace-door, sliding upon the plate *HH*, which is partly bedded in the brick-work. *I*, opening in front of fire-place, over which the fire-door slides when it is necessary said opening should be closed. *J*, section of the fire-place which is hopper-shaped, as described in the figure, and also in figures 2 and 4. *KKK*, sections of ash-pits.

*Figure 2.* Longitudinal vertical section of retorts, described in figure 1, upon which corresponding parts are marked with similar letters of reference. *L*, furnace-door. *n*, damper. *mm*, bearers. *oo*, frame of damper.

*Figure 3.* Plan over the crown of the arch *D*, showing the openings \*\*\*\*\* for allowing the flame from the furnace *E* (figures 1 and 2) to rise into the retort-oven *B*, shown in aforesaid figures. *C*, a longitudinal horizontal section of the retort, with its mouth-piece.

*Figure 4.* Plan of the furnace, showing the situation of the fire-bars *L*, and bearers *mmmm*. This furnace is splayed off from the height of *J* (figure 1) to the sides up to the springing of the arch *D*, and at the extreme end to the soffit of said

arch, so as to form it into a shape similar to the interior of a hopper.

*Figure 5.* Transverse vertical section of three large D retorts set in one oven, and heated by either a coke-oven or furnace, as may be most desirable. A, arch turned over the oven in which the retorts are placed. B B B, transverse vertical section of the retort-oven. C, D, E, vertical transverse sections of the retorts. F F, transverse vertical sections of brick-work carried up the entire length of the retort-oven, leaving between them a space G, which space, as well as the walls F F, is covered by the fire-tiles H H, upon which the retort C is placed. The walls F F have openings \* \* in them for allowing the heat from the coke-oven, oven, or furnace, which accumulates in the space G, to pass off into the retort-oven in the direction of the arrows, as more fully described by figure 7. I, one of the openings through the arch J over the coke-oven, for allowing the flame and heat therefrom to find a way into the space marked G. J, the arch over the coke-oven. K, transverse vertical section of the coke-oven. L, opening to the coke-oven in front. M, ends of the fire-bars. N, bearer. O, ash-pit. P and Q, flues running underneath the retorts D and E, from front to rear of them : see also figure 6, where they are shown in section at the foot of the back flues marked R and S. In this figure the

direction which the flame takes is shown by the arrows. This mode of setting retorts is denominated *the descending flue plan*.

*Figure 6.* A, arch turned over the oven in which the retorts are placed. J, arch over the coke-oven. K, section of the coke-oven. P and Q, vertical sections of the flues which run underneath the retorts D and E from front to rear; see also figures 5 and 9, where the same flues are marked with similar letters. RS, rising flues which lead into the main flue U U. T, damper and frame. U U, longitudinal vertical section of a part of the main flue.

*Figure 7.* Longitudinal section of walls F F (figure 5). \*\*\*, openings for allowing the heat received from the coke-oven into the space G (figure 5) to pass off in the direction of the arrows shown upon that figure. V, section of front wall, see also figure 10. III, openings in the crown of the arch J over the coke-oven. K, to allow the flame and heat from said coke-oven to pass into the space marked G (figure 5).

*Figure 8.* Plan of the coke-oven K, showing the situation of the grate-bars put in for the purpose of working it as a furnace when deemed needful. K, floor of coke-oven. M M, fire-bars. N N N N, bearers upon which the fire-bars rest.

*Figure 9.* Plan of the flues which run along under the retorts D and E, (figure 5,) and of the

rising or back flues RS, and main flue UU, (Figure 6,) and of the openings III through the crown of the arch J (figures 5 and 7). The same letters of reference being placed upon figure 9 as are used for similar parts in figures 5, 6, and 7, further explanatory remarks are not in this place required.

*Figure 10.* Longitudinal and vertical section of retorts C, D, E (figure 5). The same letters of reference are placed upon figure 10 as upon figures 5, 6, and 7, to designate corresponding parts. In addition, however, we have, V V, section of the front wall. W, sliding door with the Plate X upon which it slides, and the sliding cover Y to be placed over the part Z, connected with the ash-pit O, when K is to be worked as a coke-oven ; but to be removed to allow a draft through the fire-bars when K is to be worked as a furnace.

When these retorts are heated by K worked as a coke-oven, the oven should be charged once in twenty-four hours with half a ton of coals, which will produce about sixteen bushels of very excellent coke, together with something over a bushel of small or inferior coke. When worked as a furnace, the fire should not be allowed to extend further than about six inches beyond the fire-bars, which must always be kept covered, but on no occasion to a greater thickness than from four to six inches.

It may be useful here to remark, that when the

coke-oven K is first brought into use, the best way to get it up to a good working heat is to work it as a furnace, allowing it the benefit of all the draft the uncovered ash-pit will afford. To effect this will require two or three days, and whilst the heat is getting up, (in this case,) it will be advisable that the fire, as it burns up, should be spread over the bottom of the oven till the whole of it be covered to the depth of from nine inches to a foot in thickness, letting the stoker be careful to remove all burnt-out material so that the fire may be kept lively. By such management, we will suppose the entire of the brick-work, of which the coke-oven and the retort-oven over it are composed, is raised to nearly a white heat, and the retorts to something higher than a bright cherry-red head visible by daylight. When such is the case, let the whole of the fire be raked out of the oven, and its place supplied by ten cwt. of coals spread over the bottom at a uniform thickness; when that is done, close the opening L by the sliding door W, and open the damper T to nearly its full extent, in order that the smoke and vapour from the coals just introduced may have a free course to the main flue and thence to the chimney. Let the damper remain in that state till the coal be thoroughly ignited, which it will be in from one hour and a half to two hours. During that time, leave the part Z leading into the ash-pit O uncovered; but so soon as the

coal is well lighted, let the iron cover or door Y be placed over Z so as to prevent any external air finding its way into the ash-pit, and let the damper T be closed within about three inches. In such situation, the remaining part of the process will be accomplished in about twenty-two hours; or, twenty-four hours will elapse between the time of the coals being thrown into the oven and the time when such charge has been converted into coke and is ready for being drawn. So soon as the coke is drawn, charge again with the same weight of coals and attend to the doors, dampers, &c., as just directed, by which method there cannot arise any difficulty in keeping the retorts at a proper working heat or in producing an excellent coke. It will be desirable, however, to arrange the charging of the retorts when heated by means of coke-ovens, so that the charging of the retorts and the charging of the coke-oven may not come round at the same time. The best way will be always to charge the coke-oven when the charge in the retorts is about half burnt off, as whenever coke-ovens are used, the heat must of necessity be decreased during the process of drawing out the coke and recharging with fresh coals, which would be subject to a further decrease were the retorts charged with fresh coals also at the same time. We have endeavoured to give such instructions for the working of coke-ovens as we hope will be clearly understood, and which, if fol-

lowed, we are, from our experience, prepared to say will produce the effects the gas manufacturer wishes to accomplish, that is to say, to keep his retorts at a good working heat, and to produce from the coals used for heating them a valuable coke. We do so, from having known instances of coke-ovens having been worked in such a way as neither to produce one of the objects just mentioned nor the other. If, for instance, the coke-oven should be entirely closed by covering up the ash-pit, shutting the door of the oven and plastering both up very soon after it was charged, so as to prevent any access of air to assist in the lighting up of the coal, and if, in addition to this, the damper should be entirely closed or even partly so, hardly any one would expect that the coal in the oven would burn, or the retorts be heated; yet, strange as it may seem, such mode of operation has been resorted to.

Having made these remarks, we proceed to explain the remainder of the figures of Plate VIII.

*Figure 11* is a front view of a sight hole, frame, and lid.

*Figure 12* is a section of a sight hole, frame, and lid.

Figures 11 and 12 are drawn from a scale of one inch to a foot.

*Figure 13.* Front view of sliding door from furnace; G, door; H, cast-iron plate upon which the door slides.

*Figure 14.* Side view of sliding door for furnace, marked with the same letters of reference as figure 13.

Figures 13 and 14 are drawn from a scale of half an inch to the foot.

*Plate 9, Figure 1.* Represents a front view of five cylindrical retorts set in one oven, heated by one fire with the hydraulic main, H and dip pipes. A, A, A, A, A, the retorts as set and in a finished state. In this view the two upper retorts are shown with all the lids of their respective mouth-pieces; the two outer lower ones with the lids on, but without their being secured by a cross-piece similar to what is shown upon the middle one. The bed of these retorts is supported by an arch of brick-work B B. It is brought so far forward as to allow room enough for the stokers to charge and draw the retorts, and for a sufficient quantity of coals to be kept for supplying two or three charges with fuel for present use, luting, tools, &c. Immediately in front of the retorts is introduced (and which serves as the key-stone to the arch) a cast-iron frame of about three feet and a half long and two feet broad at the top, with an iron-door fitted to it. The bottom of the frame is struck to the radius of the arch, and of course the sides taper inwards in proportion to that radius. The situation of this opening is shown at C. This opening is for the purpose of allowing the red-hot coke, when drawn

from the retorts, to fall under the archway at *D*. *a*, the door of the fire-place; *b*, the door of the ash-pit. These doors are furnished with three perpendicular slits of about two-thirds of their height and five-eighths of an inch wide, for allowing a current of air to pass to the fire. The dimensions of these slits can be decreased by another piece made with openings to correspond, which slides horizontally in grooves in a line with the slits on the door, so as to regulate the admission of air to such an extent as the stoker may find needful. *c c c c c*, are the conducting pipes which convey the gas as it is evolved from the retorts towards the hydraulic main. *d d d d d*, front elevations of the *H* pipes. *e e e e e*, front sections of the dip-pipes with the saddles through which they are bolted to the hydraulic main. *E*, the hydraulic main. *F*, the main pipe for conveying the gaseous and other products evolved towards their respective reservoirs. *G G G G*, cast-iron columns fitted with crutches at the tops of the upper ones for supporting the hydraulic main.

*Figure 2* is a section of the same retorts, which supposes them to be cut through from the top to the bottom about the middle. In this section the hydraulic main, dip, *H* and conducting pipes are not shown. *A A A A A*, the retorts, *a a* part of the arch forming the retort-oven and brick-work contiguous to the fire-place, all of which requires to be

constructed of fire and arch-bricks. The crown of the oven is flattened by means of fire-tiles as at *b*. At the extreme end of the retort-oven are two openings which lead into the two small flues *cc*. These flues (*cc*) pass above the top of the oven towards the fronts of the retorts, and then each turns towards the centre flue *d*, which having entered, that one leads towards the main flue *H*, which it enters through the opening *e*. *f* is the fire-place, and *g* the ash-pit. *a\* a\**, arch turned over the fire-place, upon which the three lowermost retorts are bedded. There are three openings at each side of this arch marked \*, (see also figure 3\*\*\*,) for allowing the flame from the fire-place to rise into the retort-oven, which flame striking against the interior of the retort-oven, causes the retorts to be heated by reverberation. The two upper retorts may be supported by one or more wrought-iron belts brought through the upper part of the oven, and passing through a cast-iron bearing-bar placed above it, where they may be secured by means of screw-nuts in the situations wanted; or they may be supported by one or more pillars built of fire-brick to the height required as may be deemed most expedient.

*Figure 3* is a longitudinal section of cylindrical retorts set on the oven plan. *AA* are the retorts, the mouth-piece of the lower one being secured by the lid and cross-bar, the upper one is shown with-

out the lid. *f* is the fire-place with the position of the grate-bars. *g* is the ash-pit. The action of the fire in this section is as has already been described by *figure 2*; the flame from the fire-place (which is hopper-shaped as described in Plate X figures 1, 2, 4) passes through the openings marked \* \* \* (see corresponding ones in the arch *a\* a\**, figure 2) into the oven where the retorts are placed, and strikes against the sides and soffit of the arch *a a*, (figure 2,) reverberating upon the retorts *A A A A A*, by which reverberation they are uniformly heated. From the retort-oven the surplus heat is carried off by the opening shown at the extreme end of the retorts, and passes along the flue *c* towards their mouths till it comes to *d*, when it enters the middle flue lying parallel to the flue *c*; that leads into the rising part *e*, and thence into the main flue *H*. *h* is the conducting pipe which conveys the gaseous and other products from the retorts to the *H* pipe *i*, and that carries them into the dip pipe *k*, which enters into the hydraulic main *E*. In this section of the hydraulic main, the fluid by which the dip pipe is sealed is shown at *l*, through which the gas bubbles up as it is evolved, and passes along the upper part of the hydraulic main towards the main pipe *F*, (as shown in figure 1,) on its way to the washer, condenser, &c. The hydraulic main is represented in this section as supported in a similar way to what was shown in

figure 1; but instead of a brick arch for supporting the floor in front of the retorts, in the retort-house, *m* is one of a range of cast-iron beams for supporting a floor constructed of cast-iron plates. *n* is the opening for allowing the coke, when drawn from the retorts, or from the coke-ovens for heating the retorts where such are used, to fall upon the floor at *o*. This opening is covered by a cast-iron door or lid, and kept closed at all times save when the retorts or coke-ovens are being drawn.

*Plate X. Figure 1* represents a front view of three D retorts A A A, as set and in a finished state. In it the upper retort is shown without its lid; the two lower ones are represented with their lids on and as secured in their places by means of cross bars and screws in the usual way. *a*, the door of the fire-place. *b*, the door of the ash-pit, which may be similar to those described at figure 1, plate IX. (see page 153); in the references to which figure, so far as regards the conducting pipes which lead from the retorts to the H pipes, the H pipes and the dip pipes are so particularly described as to render repetition here not necessary. In this figure E represents the hydraulic main, and F the main pipe for conveying the gaseous and other products evolved towards their respective reservoirs. This figure also represents a section of three D retorts A A A, similar to those just mentioned, which supposes them to be cut through from the top to the bottom

about the middle. In this section, though the hydraulic main, the dip pipes and H pipes be shown, the connecting pipes are shown as if broken off a little above the brick-work which covers the arches and flues of the retort-oven. *a*, an arch turned over the fire-place from front to rear, with four openings left at each side, marked \*\* in this figure, and \*\*\*\* in figure 2, for allowing the flame from the fire-place to rise into the retort-oven, which flame striking against the interior of the retort-oven causes the retorts to be heated by reverberation. The parts between the crown of the arch *a* and the walls of each side of the retort-oven are filled in with fire-bricks (leaving, however, the openings \*\*\*\* through such fillings in), so as to form a perfectly horizontal bed for the two lower retorts to rest upon; and care should be taken in forming said openings that the edges of them on their upper surface should not approach nearer than two inches, at the very least, to the outside of the bottom retorts, in order that the flame may not strike directly against them, for should it do so it will very soon burn holes through each of the bottom retorts, directly opposite to where these openings are situated. Indeed it would protect the bottom retorts very much if the sides of each contiguous to the openings just referred to were cased with fire-tiles their entire length, which might be made for the purpose in lengths of about eighteen

inches, width six inches, and thickness two inches. In the front of the retort-oven is the opening *d*, which leads into the flue *e*, figure 2, and by it into the main flue H. *f* is the fire-place, and *g* the ash-pit.

*Figure 2* is a longitudinal section of D retorts, set as described in figure 1. A A are the retorts. *f* is the fire-place, with the position of the grate-bars. *g* is the ash-pit. The action of the fire in this section is as has already been described by figure 1; the flame from the fire-place (which is hopper-shaped, as described in figures 1, and a plan of which is given at figure 4 of this plate) passes through the openings marked \*\*\*\* (see corresponding ones in the arch marked *a*, figure 1) into the oven where the retorts are placed, and strikes against the sides and soffit of its arch (figure 1), reverberating upon the retorts A A A, by which reverberation they are uniformly heated. From the retort-oven the surplus heat is carried off by the opening *d*, and passes along the flue *e* to the main flue H. The upper retort is supported by one or more pillars (marked B, figure 1) built of fire-brick, or by a wall, built of such material, its entire length, as represented in this figure.

*Figure 3* is a plan of the top flues *e* (figure 2) which lead towards the main flue. In this plan each retort-oven has its own separate flue, which leads towards a short main flue that rises directly

into the chimney, and merely crosses a portion of the end of the retort-bed, instead of running the entire length thereof, as is the more usual practice. This arrangement of top flues will answer well when only two or three ovens are required, but in ranges of a greater number it becomes so complicated as to render its adoption impracticable.

*Figure 4* is a plan of the fire-place, in which the situation of the door-way thereto and the fire-bars are shown; the brick-work round the fire-place is to be carried up to the height shown in figures 1 and 2, and from that height it is to be splayed off at the sides as shown in figure 1, and at the end as shown in figure 2; so that when the work is entirely completed, it will form a shape something similar to a hopper. The filling in may be of common bricks laid in lime and sand-mortar, but it must be finished either with fire-bricks laid edgewise and well grouted with fire-clay or with two courses of fire-bricks, as may be most convenient.

*Figure 5* is a front view of doors and frames for the fire-place and ash-pit. The lower door, or that for the ash-pit, is cast with three perpendicular slits, each five-eighths of an inch wide and eight inches long, for allowing a current of air to pass to the fire. The dimensions of these slits can be decreased by another piece (figure 7) cast with corresponding openings, which slides in grooves horizontally, so that thereby the admission of the air can be regu-

lated to such a degree as the person having charge of the fire may deem needful. The grooves and slide are shown in section at figure 6.

*Figure 6.* Vertical section of furnace-doors and frames for showing the thickness of the metal (half an inch) and distance which the frame is intended to be brought within the brick-work (six and a half inches).

*Figure 7.* Front view of the piece which is intended to slide over the ash-pit door, described in figure 5. This may be made of boiler-plate one-fifth of an inch thick, or of cast-iron three-eighths of an inch in thickness, with the slits as shown.

*Figure 8.* Side view of a fire-bar for a retort furnace of a very convenient length, and of the best shape for ensuring durability.

*Figure 9.* Plan of the upper face of said fire-bar; its entire length is two feet six inches; the bearings at each end are three inches by three inches, and depth three inches; the width of the upper face of the fire-bar between the bearings is two inches and a quarter.

*Figure 10* is a section of figure 8 at its greatest depth; width at the top two inches and a quarter; depth of the upper or square part of the bar two inches; of the lower or circular part, three inches: the circular part of the bar is bevelled off at each side, so as to leave the lower edge about three-quarters of an inch broad.

*Figure 11.* Side view of one of the bearing bars, upon which the fire-bars rest; its extreme length is one foot eight inches, and depth three inches.

*Figure 12.* Transverse section of the bearing bar, figure 11, which shows that it is two inches in thickness by three inches deep.

The reader is here informed that figures 1, 2, 3, and 4, of Plate X., are drawn from a scale of a quarter of an inch to a foot, and figures 5, 6, 7, 8, 9, 10, 11, and 12, from a scale of one inch to a foot; he can, therefore, from them prepare working drawings for setting three D retorts as therein described; and whilst speaking of that particular plate it may be observed, that the same remark is applicable to all the plates in which different modes of setting different kinds of retorts have been delineated.

Having now described such retorts and modes of setting them as we think most applicable to the purposes of the gas-light manufacturer, whether the manufactory be upon a small or upon a large scale, we shall draw this chapter to a conclusion by remarking, that we are well aware we have not given drawings or descriptions of one half of the methods which have been adopted at several gas manufactories for setting retorts: we refrain from doing so because we think no useful end would be thereby attained, as *all the plans in use at the present day* are but modifications of those we have described. Whilst in some manufactories the flue plan, as we

have described it, is still adhered to; in others the heating of three, five, or seven (or even more) retorts in one retort-oven, by means of one or more fires on the furnace system, is the favourite practice; and whilst others, again, prefer heating three or five large retorts in one retort-oven, by means of a coke-oven; whilst some, again, prefer ascending and some descending flues, yet, as has already been observed, all these methods arise out of plans we trust we have so sufficiently described as to render them perfectly intelligible to the practical reader, who, with our plates and descriptions, we expect will find no difficulty in constructing his retort-ovens, furnaces, and coke-ovens, so as to answer for any number of retorts he may deem it expedient to set in one batch or nest. Our plates, we know from much experience (as they are all made from working drawings of our own made by ourselves, from which we have erected apparatus at various places and to a very great extent), are particularly applicable to all establishments where from three to one hundred elliptical, kidney-shaped, or large D retorts are required, and more particularly those described by figures 1, 2, 6, 7, 8, and 9, Plate VII.; figures 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, Plate VIII.; figures 1, 2, and 3, Plate IX.; and figures 1, 2, 3, and 4, Plate X.

## CHAPTER VI.

On Carbonization, so far as relates to the most beneficial time for working the retorts and the per centage at which it may be carried on.

EXPERIENCE has taught every gas manufacturer that the well-being of every gas-light establishment mainly depends upon the retorts being kept at a good working heat, and upon the expense of coal or other material used for the purpose of heating them being at as low a per centage upon the cost of coals used in the retorts as it is possible. These are things of the utmost importance so far as the manufacture of gas is concerned; we must admit, however, that occasionally other things occur which militate against the proprietors of gas shares obtaining a *fair* profit for their investment, which we intend to notice in their proper place; but, if the retorts are not skilfully and economically worked, no saving in any other department can make good the loss which will thence inevitably arise. Hence numerous have been the experiments made for the purpose of decreasing the expenses which arise from the destruction of the retorts; for carrying on the process of carbonization at a low per centage; and for obtaining the greatest quantity of gas in the

least possible time, and that gas of the best quality.

As the different shapes of the retorts, with the general results arising from the use of each, have been spoken of in the preceding chapter, we shall now confine our inquiries more particularly to the length of time in which the charge of coals in a retort is most advantageously worked off, and the per centage at which carbonization ought to be carried on.

In the early period of this mode of obtaining light, it was not at all uncommon to hear of attempts to decompose coal in such prodigious masses as would require more than twenty-four hours to work off at one charge. When such was the case, more coal was used for heating the retort than the quantity it contained from which gas was to be extracted. Retorts of as much as twenty inches in diameter have been heard of, and the time alluded to is that when such were used. When these large retorts were filled with coal, and that coal submitted to the distillatory process, every one must be aware that a considerable time would elapse before the entire of the coal contained in the retort could become heated to redness; and, as the outer surface would first become so, it would, after being decomposed and converted into coke, become so close and compact a coating to the more central part of the coal in the retort as to render the passage of the gas from that

part extremely difficult ; and it would also follow, that although the quantity of gas evolved during the first two or three hours of the process might be very considerable, it would hourly decrease in volume, and so much so, that during a very considerable portion of the latter part of the distillatory process there would not be so much gas generated as would repay the manufacturer for the coals necessarily used for keeping his retort at a proper working heat. A system like this could not be expected to continue in use for any length of time : its errors were too palpable to remain unnoticed. At the time it was practised, such as were engaged in the manufacture of gas considered that, if the expense of carbonising could be reduced to less than fifty per cent. on the coals carbonised, further reduction could hardly be expected. A few years' practice, however, proved how little was then known about the matter ; for, instead of carbonization being carried on at fifty per cent., it has, in some instances, been reduced to as low as sixteen per cent., when working retorts on an extensive scale. This reduction, however, was not made all at once, nor was it altogether effected without increasing the wear and tear of retorts, or otherwise, by a loss in the quantity of gas procured from a given quantity of coals. The retorts were first reduced from twenty inches in diameter to twelve, which last named size were for a considerable time generally used ; but now

have, in their turn, given way in most cases to the elliptical, small, or large D-shaped retorts.

At the time when cylindrical retorts were used, it became a question with some whether the manufacturer could not increase his profits by working his retorts at a lower temperature than was necessary to obtain at the rate of about 7,400 cubic feet of gas from a ton of the best Newcastle coals; to effect which, the length of time necessary for accomplishing the process would be eight hours—each retort being charged with 160 pounds of coals, and the heat worked at a bright cherry-red visible by day-light. To ascertain the fact, numerous experiments were made at different gas establishments, and with retorts of such shapes as were generally in use, the results of all which tended to prove in favour of eight hours' charges, the retorts being worked at a bright cherry-red heat visible by day-light: in all places where, as in London, the price of coal is high, and where from the form of the retort, 160 pounds of coal formed a proper charge, as well as being particularly applicable to the twelve-inch cylindrical, and twelve-inch square, or to the twelve-inch D retorts. Where coals are very cheap, working the retorts at a low temperature may not be of any great consequence as it affects the manufacturer; but generally speaking, it is a system which ought carefully to be guarded against. When it is considered that by working the re-

tort at a low temperature, not more than about 5,926 cubic feet of gas can be expected from a ton of the same description of coals, which, if decomposed at a higher temperature, produces 7,400, there evidently arises a loss, upon each ton of coal carbonised, of 1,474 cubic feet of gas, which at the London price, 9*s.* per 1,000 cubic feet, amounts to 13*s.* 3*d.* Under such circumstances, it will not be difficult to understand, that even where coals are cheap, it cannot be to the advantage of the manufacturer to work his retorts at a low temperature. We are aware that some of our readers may object to our speaking of 7,400 cubic feet being the production of gas from a ton of Newcastle coals; we are also aware, that the House of Commons has been informed within the last four years by a gentleman, who is said "to possess a sound knowledge of chemistry, joined to such mechanical talent and indefatigable diligence, as qualify him to conduct with success any great undertaking committed to his care," that the average quantity of gas procured in London from a ton of coals is 8,500 cubic feet; that at Birmingham the proportion is 6,500; at Macclesfield, 6,720; at Stockport, 7,800, (half Cannel coal used); at Manchester, 9,500 (Cannel coal used); at the Liverpool Old Gas Works, 8,200 (Ormskirk and Wigan slack); at the Liverpool New Gas Works, 9,500 (Wigan Cannel used); at Bradford, 8,000, at Leeds, 6,500, at Sheffield,

8,000, (partly Cannel,) at Leicester, 7,500, at Derby, 7,000, and at Nottingham, 7,000. We are further aware, that the managers of some of the London Gas Companies, at the present day, speak of obtaining about 9,600 cubic feet of gas from a ton of coals, but this is the maximum spoken of, others quote 9,000 as the result of their average working; but giving the manufacturer the benefit of the highest amount mentioned, which, if procured at all, must be at an immense cost of fuel for heating the retort, and at an enormous expense also for wear and tear; our position is not weakened as regards the working retorts at a low temperature; on the contrary, additional strength is thereby given to it; for at a low temperature, the quantity of gas produced will not be increased beyond what we have already quoted, that is to say, 5,926 cubic feet to the ton (say in round numbers 6,000); whilst taking 9,000 cubic feet to the ton, as the present average produce on the other side, there would arise a loss upon each ton of coal carbonised of 3,000 cubic feet of gas, which, at the London price, 9s. per 1,000 cubic feet, amounts to 17. 7s. Taking into consideration (from the remarks just made) the profits on one hand, and comparing them with the losses on the other, it would appear to be more advantageous to charge such retorts, as we have been speaking of, with 160 pounds of coals, and to work them at such a heat

as would, from a ton of coals, produce from 7,400 to 9,000 cubic feet of gas.

Whilst some were pursuing experiments, for the purpose of ascertaining whether it would be more profitable to work the retorts at high or at low temperatures, others supposed that it would be more profitable to work the retort at six hours' charges, decreasing the quantity of coals submitted to carbonization, at one charge, from 160 to 120 pounds, or even to 100 pounds. The parties who favoured the short charges were led to expect immense advantages from their adoption, from considering that, when the retorts were worked at eight hours' charges, four-fifths of the gas produced was evolved during the first six hours of the process, and from having probably noticed also that the gas produced during the two last hours of the charge was of very low illuminating power. That when retorts are worked at eight hours' charges of 160 pounds of coal to each, and at a bright cherry-red heat visible by daylight, four-fifths of the gas which would be produced during the entire eight hours would come over during the first six hours of the charge, the following table being the results of numerous experiments, made in the large way under my own observation, will very clearly demonstrate. It may not be improper to remark, that I was led to make these experiments during the summer of 1816 (the reader conversant with matters con-

nected with gas-lighting will be aware there was not, at that time, such a thing as a station-meter in existence, nor any other gas-meter that could be depended upon for registering the quantity of gas which might pass through it), from having found it difficult to ascertain the quantity of gas generated by any kind of approximation during the short days of the preceding winter, when the street-valve frequently did not remain shut during one entire charge. As one part of my duty, then, was to report the quantity of gas daily generated at the works of a London Gas Company with which I was then connected, I considered that, by a series of experiments made on different kinds of coal, I might obtain such a knowledge of the proportions in which the gas was evolved, as would furnish me with proper materials for making my calculations from, even should the communication between the street-mains and the gas-holder not be shut off more than half the time of one charge.

*Table exhibiting the Ratio at which the Gas is evolved from Newcastle Coals, when the retorts are worked at Eight Hours' Charges :—*

During the	1st hour of the process	2,000	cubic feet are generated.
„	2nd	1,495	„
„	3rd	1,387	„
„	4th	1,279	„
„	5th	1,189	„
„	6th	991	„
„	7th	884	„
„	8th	775	„

Total 10,000 cubic feet obtained during the process.

Since the station-meter has been adopted, I have had ample means of verifying the above, and find the proportions as stated in the above table, so nearly approaching to what the station-meter has indicated, that I see no necessity for alteration therein. I may here remark, that no gas establishment, however small, ought to be without a station-meter ; but as there are some, even at this day, not provided with one, to persons having the management of *them*, the above table will be found useful for filling up their carbonising account-book, when circumstances will not permit of the valve from the gas-holder towards the street or supply-pipe being kept closed during an entire charge ; for if the total be considered as one, then the cubic feet of gas as therein stated, to be generated during each hour of the charge, will be decimal parts of one. It follows, therefore, that if the quantity of gas actually generated during any part of the process be known, the heat of the retort continuing equable throughout the entire charge, the total quantity of gas made during that entire charge may be known also, by dividing that which is known by the sum of the decimals in the table corresponding with the hours upon which the observations may have been made. Thus, for example, supposing such a number of retorts charged as produced, from the beginning of the second to the end of the fifth hour of the process, 6,741

cubic feet of gas, and we wished to know what quantity would be produced during the entire charge, by referring to the table, it will be found that—

During the 2nd hour of the process, 1495 cubic feet of gas are generated.

„	3rd	„	1387	„
„	4th	„	1279	„
„	5th	„	1189	„

—  
Their sum 5350 in this case will be the divisor.

Then  $6,741 \div 5,350 = 12,600$  cubic feet, the quantity of gas produced during the entire charge.

Having spoken at some length as to working the retorts at eight hours' charges, we may now notice, that it has become a very prevalent practice to work them in several establishments at six, and in some, at four hours' charges; the four hours' charges are not, however, much practised, except where Cannel-coal is used for the production of gas. In the former editions of this work we gave it as our opinion, that, in most cases, it would be to the advantage of the manufacturer to work his retorts at eight hours' charges, and the subsequent practice of many years has not had a tendency to produce any considerable change in the opinions we then expressed: for whenever retorts are worked at short charges, a smaller quantity of coals must be used for each charge; and to work that diminished charge well off, the retort must be kept at a very

high temperature : for, when the short processes are followed, the frequent charging and drawing so cools the retorts, if attempted to be worked at such a heat, as is best adapted for eight hours' charges, as to make it very difficult to keep that degree of heat up, thus rendering it necessary to keep the retorts at nearly a white heat, in order that the coal may be properly carbonised within the period required. The more rapid destruction of the retort will be one of the consequences, and the lower specific gravity of the gas another ; for any heat above a bright cherry-red visible by day-light will have a tendency to make the gas lighter, consequently of less illuminating power ; and, though it may be increased in bulk, it will not at all in the same proportion be increased as to the quantity of light it may afford, for reasons I shall elsewhere state.

That the expense of heating the retorts will be increased where short charges are worked, there can hardly be a doubt, and that such is the case, I may here mention that my own practice during a great number of years, in the working of elliptical and small D-shaped retorts set in ovens, and heated by means of furnaces, has on the gross fallen, for the article of fuel for heating the retorts, under thirty per cent. upon the value of the coals used for making gas. In an official document, laid before a Committee of the House of Commons in

1837, it was reported, that, in London, where it states six hours' charges prevail, thirteen bushels of coke are used for heating the retorts for every ton of coals carbonised. It states, also, that every ton of coals used for making gas produces thirty-six bushels of coke, and that the coke is sold for 12*s.* per chaldron; further, that 17*s.* is the average price paid per ton for coals by the London gas manufacturers. Now, if we can suppose the above data to be correct, carbonization is carried on in London at about twenty-six per cent. upon the value of the coals carbonised, which fact we come at thus:—One ton of coals cost 17*s.* To carbonise it, requires thirteen bushels of coke, which sells at 12*s.* per chaldron of thirty-six bushels, consequently one bushel is worth fourpence: therefore, 13 bushels  $\times 4 = 52$  pence for coke for fuel, and 17*s.*, the price of one ton of coals  $\times 12 = 204$  pence, is the cost of the coals used for making gas  $= \frac{52}{204} = \frac{13}{51}$  or  $\frac{1}{4}$  of the cost of the coals carbonised in the retorts. Were the facts really so, it is evident a considerable advantage would be gained by the adoption of short charges in the saving of coals or coke used for fuel; but, unfortunately for the party who made this statement, no single gas establishment in London is to be found where carbonization is carried on at so low a per-centage: some of the managers of the best arranged and best paying ones in the metropolis do not pretend that they heat their retorts at

a less expense than thirty per cent. upon the cost of the coals used for making gas, and it is generally believed by persons acquainted with the operations of the London gas companies, that the average cost of carbonising in the different gas-works situated in London, Westminster, and Southwark, is nearer forty per cent. than thirty. Supposing, therefore, that 9,000 cubic feet be the average produce of gas from a ton of coals, and that only 7,400 would be obtained from a like quantity were the retorts worked at eight hours' charges, we are of opinion, after all, that when we have set off against the increased quantity of gas obtained, its illuminating inferiority and the increased cost for fuel and for replacing burnt-out retorts, and fire-bars arising out of working the retorts at short charges, as well as for increased expenses for repairs of furnaces, we shall find at the year's end little if any saving arising out of the departure from working the retorts at eight hours' charges with about 160 pounds of coal to one retort for each charge. Indeed, we are quite certain, that where cylindrical or the small D-shaped retorts are used, the eight hours' charges will always be the most advantageous to the manufacturer. Where the elliptical, the kidney-shaped, or the large D-shaped retorts are used, we are of opinion that a charge of 120 pounds of coal may be worked off advantageously in six hours; and in cases of emergency, such shaped

retorts might be worked at four hours' charges with one hundred pounds of coal to each for a charge, in either case causing the temperature of the retort to be kept a little higher than to afford a bright cherry-red heat visible by day-light, being very careful, however, to prevent the retort from approximating towards incandescence, which must be guarded against for reasons already given, and which, when we speak of the chemical constitution of coal-gas, will be more fully dwelt upon.

Were it requisite, we could, from numerous experiments made in the large way at different times and under different circumstances, most satisfactorily prove the general superiority of the longer process to the shorter ; but we deem it not necessary now to do so, though we considered, when our former labours were laid before the public, it was needful to furnish our readers with the details of various experiments made with cylindrical and other retorts worked at six and eight hours' charges respectively. The first of the experiments alluded to was carried on for one week with ninety-two cylindrical retorts worked at six hours' charges; in which time 857,667 cubic feet of gas, about 110 chaldrons of coke and breeze,  $7\frac{3}{4}$  tons of coal tar, and 1,864 gallons of ammoniacal liquor, were produced ; value altogether, at the then selling prices of the products, 870*l*. The expenditure for producing the above result was the cost of 140 tons of coal for making gas, and of

58 tons of coals for heating the retorts, and an increase of the stokers' wages (two more being necessary than would have been required had the retorts been worked at eight hours), amounting altogether to 360/. The average quantity of gas procured from one ton of coals during the entire experiment amounted only to 6,126 cubic feet.

Another experiment was continued also for a week with cylindrical retorts worked at eight hours' charges, in which time the same quantity of gas, viz. 857,667 cubic feet of gas, was obtained; to procure which, however, upon the average of the whole week, only seventy-four retorts were kept in action. In addition to the gas already named, there was, in the carrying out of this experiment, obtained 103 chaldrons of coke and breeze,  $6\frac{2}{3}$  tons of coal tar, and 1,536 gallons of ammoniacal liquor; value altogether, at the then selling prices of the products, 851/. The expenditure for producing the above amount was, for 116 tons of coals for making gas, and 29 tons of coals for heating the retorts, 266/. The average quantity of gas obtained from one ton of coals, during the entire experiment, amounted to 7,393 cubic feet.

By comparing the results of the two experiments just noticed, the reader will observe, that the same quantity of gas was generated under one as under the other mode of operation, notwithstanding there were fewer retorts used and less coal carbonised

when the retorts were worked at eight hours' charges than when they were worked at six hours' charges; and that the expense of fuel for heating the retorts in use when the distillatory process was extended to eight hours was considerably less; and the proportion of gas obtained from a ton of coals in that case greater than when the process was only continued to six hours.

Now if from the products when working at	
six hours' charges . . . . .	£ 870
we take the products when working eight	
hours' charges . . . . .	851
	<hr/>
we have a difference of . . .	£ 19
which being subtracted from the difference between	
the expenditures as already specified, viz.	

Expenditure when working the retorts at	
six hours' charges . . . . .	£ 360
Ditto ditto at eight hours' charges	266
	<hr/>
Difference . . . . .	94
Less . . . . .	19
	<hr/>
leaves . . . . .	£ 75

as a balance in favour of working eight hours' charges for one week over what was the result when the retorts were worked at six hours' charges, 857,667 cubic feet of gas being produced in each case.

Having compared the quantity of coals actually used when working six hours' charges, with what was used to produce the same quantity of gas from eight hours' charges, I shall next point out the quantity of gas generated when working the same number of retorts at eight hours' charges, which had been worked at the process of six hours. The experiment was carried on for one entire week during each day, of which the average number of retorts worked was ninety-two. There were produced from this series of experiments 1,070,000 cubic feet of gas, 128 chaldrons of coke and breeze, 8 tons of coal-tar, and 1,945 gallons of ammoniacal liquor, value altogether, at the then selling prices of the products, 1,060*l*. The expenditure for producing the above amount was, for 144 tons of coal for making gas, and 36 tons of coal for heating the retorts, 330*l*.; the quantity of gas obtained from one ton of coals during the entire experiment amounted to 7,430 cubic feet.

Products per experiment just named . . .	£1,060
Products per experiment, when 92 retorts were worked at an average at six hours' charges, see page 176 . . . . .	870
	<hr/>
Difference in favour of eight hours' charges	£190
	<hr/>

Expenditure when working 92 retorts, at six hours' charges . . . . .	£360
Expenditure when working 92 retorts, at eight hours' charges . . . . .	330
<hr/>	
Leaves a difference of expenditure in favour of eight hours' charges, of . . . .	30
To which if we add the difference in favour of eight hours' charges for products .	190
<hr/>	
we have . . . .	£220

From the above recapitulation, it appears, that, by working ninety-two cylindrical retorts for one week, at six and at eight hours' charges respectively, there would be a balance in favour of eight hours' charges amounting to 220*l.*; and in this proportion, let the number of retorts be what it may, an advantage will always be gained by working cylindrical retorts at eight hours' charges, instead of adopting the six hours' process.

After the reader has carefully examined the results of the three experiments as just given, it is expected it will not be necessary to make any additional comment on the imaginary advantage from decreasing the time for working off one charge of the retort, particularly as the care which was taken in making them, enables the author to lay them before his readers, as such as can be depended upon. If we, however, refer to the two first, and pursue our cal-

culations a step further, we shall find still greater advantages arising from working cylindrical or small D-shaped retorts at eight hours' charges; for we consider it has been proved, that when such retorts are worked at six hours' charges, they do not remain serviceable more than about two-thirds of the time they would do if worked at the eight hours' process. This more rapid destruction of the retorts arises principally from the necessity of working them at a higher temperature than would be required were they otherwise worked; for unless they be kept at almost a white heat when working at six hours' charges, the frequent charging and drawing so cools the retorts, that, were they not kept at that high temperature, they would soon be unable to extract the gas from the coals with which they were charged, owing to their decrease of temperature, so that, instead of drawing good bright coke from them at the end of each charge, the retorts would contain a great quantity of tar, and the coal would not be half carbonised. In working at a very high temperature, the fire requires to be increased, and consequently the grate-bars are more rapidly burnt out, and the destruction of every part of the fire-work is very materially accelerated.

The following statement is made for the purpose of bringing before the reader the annual balance in favour of working eight hours' charges with cylindrical or small D-retorts, over those of six hours,

when it is required to produce the average weekly quantity of 857,667 cubic feet of gas by either process.

At page 178, the balance in favour of working eight hours' charges for one week, over those of six hours, the quantity of gas as above mentioned being produced in either case, is stated at 75*l.*, or at the rate of 3,900*l.* per annum, and this balance is for coals, products, and labour only. The first cost of setting one retort on the flue-plan is about 23*l.* when four are heated by one fire; this includes pipes to the hydraulic main, coke, hearth, &c., consequently a series of four retorts set in that method would cost 92*l.* The cost of replacing a cylindrical or small D-retort so set, including repairs of fire-work, &c., is about 15*l.*, or at the rate of 60*l.* for a series of four retorts.

By the six hours' process, it would require ninety-two retorts to be kept constantly at work to produce 857,667 cubic feet of gas per week. Retorts so worked would not at an average, remain serviceable (if set on the flue-plan) more than four months, consequently 276 would be burnt out in a year, and the cost of replacing each being 15*l.*, the cost of replacing that number amounts to. £4,140

Wear and tear of grate-bars, &c. . . . . 140

---

£4,280

By the eight hours' process, it would require seventy-four retorts to be kept constantly at work to produce 857,667 cubic feet of gas per week. Retorts so worked, if set on the flue-plan, would remain serviceable six months, consequently there would be but 148 burnt out in a year: the cost of replacing each being reckoned 15*l.*, the cost of replacing that number would amount to. . . . . £2,220

Wear and tear of grate-bars, &c. . . . . 80

---

£2,300

---

Balance in favour of eight hours' charges, so far as relates to the wear and tear of retorts, furnace-bars, &c. . . . . £1,980

If to the above we add the balance for coals, products, and labour, as already stated at page 182 . . . . . 3,900

---

their sum . . . . £5,880

shows the annual balance in favour of working eight hours' charges (with cylindrical or small D-retorts set on the flue-plan), when it is required to produce in that time, by either mode of working, 44,598,684 cubic feet of gas.

Considerable as is the advantage gained by the manufacturer from working cylindrical or small

D-shaped retorts at eight hours' charges instead of six, both as regards the products, and also the wear and tear of retorts, yet the practice of working these descriptions of retorts at six hours' charges continues in many gas establishments to be persevered in.

The cause which perhaps first induced the manufacturer to work cylindrical retorts at less than eight hours' charges was a want of sufficient room in the gas-holders for the gas necessary for the light he had to supply, which led him to shorten the process of carbonization, under an idea that he would procure a greater quantity of gas in a shorter time, he being well aware of the much more rapid generation of the gas during the beginning than towards the end of an eight hours' charge. Instead, however, of his obtaining a greater quantity of gas in a given time from a given number of retorts worked at six hours' charges than he would have obtained had he worked the same number of retorts at eight hours' charges, we think we have said enough to show he could not by any possibility obtain so much, and that the smaller quantity of gas would be generated at more expense than the greater. We therefore repeat, that on all occasions where the cylindrical or small D-shaped retorts are used, it is the most advantageous to work them at eight hours' charges. In order in some measure further to elucidate this point, we

may observe, that, whenever pit-coal is to be submitted to the process of distillation, the time for completing the process cannot be shortened to less than eight hours, unless we have the means of exposing the coal to the action of the heat in thin strata, say four inches. When coal is so exposed in cylindrical retorts, that retort which, when worked at the eight hours' process, is capable of effectually carbonising 160 pounds of coal, would only carbonise about forty-eight pounds, which is the weight of a layer of four inches in thickness on the bottom of the retort; the section of a cylinder whose altitude is four inches, base eleven inches, and length about six feet, being in that ratio to the capacity of the retort whose inside diameter is twelve inches, and working length about six feet. We have been told by persons having the management of the carbonising department in different manufactories, that when the six hours' process is followed, the charge is from 100 pounds to 120 pounds. In such cases, the masses of coal are by no means so diminished as to cause the process to be performed advantageously. When the retort is so charged and worked, the heat proceeding in all directions towards the centre of the coals therein, will meet with nearly the same obstacles to prevent the extrication of the gas as if the retort had been charged with 160 pounds of coal.

With respect to six hours' charges, when

worked off by cylindrical or small D-shaped retorts set on the oven-plan, the same arguments, which we have already advanced when speaking of retorts set on the flue-plan, will hold good in favour of eight hours' charges here also. We may, therefore, from what has been said, conclude that, whenever cylindrical or small D-shaped retorts are used, let the mode of setting be what it may, the operator ought never to work off his charge in less than eight hours, taking care to keep his retorts at such a heat as will ensure his procuring from 7,400 to 8,000 cubic feet of gas from one ton of coals.

When the semicircular (or large D-shaped), elliptical, or kidney-formed retorts are used, the charge can be worked off in much less time than it can be with the cylindrical or small D-shaped retorts. In using any of these descriptions of retorts, it would be advisable to introduce the coal into them by means of sheet iron trays (say three trays for each retort) extending, when placed end to end, to nearly the entire length of the retort, and being of such breadth and form as to fit to the bottom of the retort (not over close), and turned up at their sides and ends about four inches. By having two sets of such trays for the retorts in action, the time usually lost in charging and drawing would be greatly decreased, as would also be the stoker's labour. By the mode most generally practised, the raking the red-hot coke out of the retort

is not only very laborious, but also attended with much loss of time, both which might be avoided by the mode suggested; for by using trays, the spare ones might be charged with the proper quantity of coal preparatory to the time for drawing, by which means almost the only time occupied in the operation of drawing and recharging would be that required for breaking the joints of the mouth-piece lids, reluting them, and restoring, and securing them in their places. This part of the work, too, might also be abbreviated by having a spare set of lids ready luted to replace those taken off as soon as the new charge was introduced into the retort. To these advantages, the less loss of heat by the retort cooling from its being internally exposed is to be added.

Carbonization, when carried on by means of semicircular, large D-shaped or kidney-formed retorts, when properly set, is always effected with greater advantage than it can be by cylindrical or small D retorts; for as the great art of making gas to advantage depends upon exposing coal to the action of heat in thin strata, such kind of retorts as we have been speaking of are particularly adapted to the purpose. The large D retorts, if worked at a heat rather higher than a bright cherry-red visible by day-light, will work off a charge of 160 pounds of Newcastle coals in four hours, and produce, at an average, 9,600 cubic feet of gas from a ton of New-

castle coals, with an increase in bulk of coke (particularly adapted for use in the parlour-fire and also for culinary purposes) of forty per cent. upon the quantity of coal carbonised. Consequently, five large D retorts will produce as much gas during the space of twenty-four hours as can be produced from twelve cylindrical retorts worked at eight hours' charges with 160 pounds of coal to each retort, every charge, or sixteen cylindrical retorts, worked the same length of time with 120 pounds of coals to each retort for one charge.

As what has been said on the subject of carbonization, when carried on by means of the semicircular or large D-shaped retorts, applies in all essential points to the working of large square retorts, it will not be necessary to dwell further upon this case in this place.

The next mode of carrying on the process of carbonization is by means of elliptical retorts. In the elliptical retort is combined the durability of the cylindrical one with the advantages obtained by exposing the coal in a *thin* layer to the action of the heat upon a large surface: therefore, when it is used, the process will be accomplished in about four hours. I have had for many years opportunities of making my observations upon the working of elliptical retorts, and the results of these observations induce me to pronounce them most admirably adapted for promoting the interest of the

gas manufacture. Five elliptical retorts are capable of carbonising thirty-two hundred weight of coal *per diem*, and of generating from that quantity of coal about 17,000 cubic feet of gas, or at the rate of 12,590 cubic feet to the ton; but, on the average mode of working, we may consider that five such retorts will in twenty-four hours carbonise twenty-seven hundred weight of coals, and produce from 12,000 to 14,000 cubic feet of gas, or from 8,890 to 10,370 cubic feet from one ton of coals. From twenty-seven hundred weight of coals, when elliptical retorts are used, will be produced a chaldron and a half of saleable coke. We may here remark, that the stokers find it less laborious to work elliptical retorts, even when worked at four hours' charges, than it is to work the same number of cylindrical or small D-shaped retorts at eight hours' charges, their shape affording more room for raking out the coke more rapidly than either of the other shaped retorts affords; and the coke, not being so compact when produced in the elliptical retort, is drawn therefrom with much less trouble than it can be from retorts of a circular or D shape.

As experience has taught us that the most favourable results arise to the gas manufacturer by charging elliptical retorts with 120 pounds of coals to each, and working such charge off in four hours, I shall from these data calculate what number of elliptical re-

torts would be necessary to be worked for producing 857,667 cubic feet of gas in one week (supposing 10,370 cubic feet to be produced from one ton of coals), the coal it would require for producing it, and the quantity of coal necessary for fuel for heating the retorts if set five in one oven, with the products obtained; and after having stated the annual cost for retorts and grate bars, strike a balance between the most favourable mode of working cylindrical retorts and that of working elliptical retorts.

I find that, in employing elliptical retorts, that 35 retorts would be required to be kept constantly at work; that these would carbonise in one week nearly 83 tons of coals; and that  $26\frac{1}{2}$  tons of coals would be required as fuel for heating them, making the weekly expenditure for coals about £199.

The amount of products would be, for 95	
chaldrons of coke and breeze, for $3\frac{1}{2}$	
tons of coal tar, for 1,200 gallons of	
ammoniacal liquor, and for 857,667	
cubic feet of gas . . . . .	£789

To work the number of retorts stated to be in action when cylindrical retorts were worked at eight hours' charges, it required ten stokers by day and ten by night; but to work the number of elliptical retorts as above, it would require only five day and five night stokers;

consequently there would, in the latter case, be ten less in pay, and their wages, at 36s. each per week, would be . . . £18

The above sum of £18 being in reality a saving arising to the manufacturer by working elliptical retorts, therefore it must be added to the products as above

stated, and we shall then have . . . 807

as the total for products obtained at a cost for coal of £199, as has been already stated.

Now, if from the products when working cylindrical retorts at eight hours' charges, see page 177 . . . . . £851

we take the products arising when working elliptical retorts, at four hours' charges, when producing the same quantity of gas as the cylindrical ones as above . . . 807

the difference is £44

which being subtracted from the difference between the expenditure in each case, that is to say,

Expenditure when cylindrical retorts are worked at eight hours' charges . . . £266

Expenditure when elliptical retorts are worked at four hours' charges . . . 199

67  
less 44

leaves £23

as a balance in favour of working elliptical retorts at four hours' charges for one week, when producing a like quantity of gas as had been produced by working cylindrical retorts at eight hours' charges, or at the rate of £1196 per annum on coals, products, and labour.

At page 183, the annual expense of cylindrical retorts when worked at eight hours' charges, together with the wear and tear of grate bars, is stated to be, when worked so as to produce 44,598,684 cubic feet of gas in that period, £2,300. When elliptical retorts are used as above specified, they will remain in a sound working state about twelve months: if, therefore, we calculate the expense of elliptical retorts with their appendages for one year, and compare the various results one with another, we shall find how far the elliptical retorts are advantageous.

By using elliptical retorts, worked at four

hours' charges, about 35 retorts would

be required to be kept constantly at work

to produce 857,667 cubic feet of gas

per week: such retorts so worked would

remain serviceable twelve months, con-

sequently there would be only 35 burnt

out in one year. The cost of replacing

them, at £18 per retort, would amount to

£630

Wear and tear of grate bars . . . . .

60

---

£690

---

The expense incurred by the annual destruction of cylindrical retorts, &c., when worked at eight hours' charges, so as to obtain 44,598,684 cubic feet of gas, has been stated at . . . . £2,300

The expense incurred by the annual destruction of elliptical retorts, &c., and of like power, as above . . . . . 690

---

Annual balance in favour of elliptical retorts £1,610

To which we are to add the annual balance in coals, products, and labour in favour of the employment of elliptical retorts as above described, over that of cylindrical ones, worked at eight hours' charges . . . . . £1,196

---

The sum £2,806

is the total annual balance in favour of elliptical retorts, when compared with results produced during the same period, and when the same quantity of gas is procured by means of cylindrical or small D-shaped retorts.

If we add to the last named balance, the annual balance in favour of working cylindrical retorts at eight hours' charges, over such retorts worked at six hours' charges, when it is required to gene-

rate by either 44,598,664 cubic feet of gas in a year, as stated at page 183 preceding . . . . .	£5,880
--	--------

---

We have £8,686

saved in one year, by using semicircular (or large D-shaped), kidney-formed, or elliptical retorts, in preference to carbonising with cylindrical, or small D-shaped retorts, let the latter be set as they may, and worked at six hours' charges, with 120 pounds of coals to each as an average charge.

In concluding this chapter, we deem it necessary to apprise our readers, that we have considered it expedient to abide by the prices paid for coals and labour, and received for products given in the former editions of this work, because, by doing so, we show what were the results as to profits, when working at such prices as were then the current ones, viz. coals for making gas, about 38 shillings per ton; coals for heating the retorts, about 31 shillings per ton; stoker's wages 36 shillings per week; coke produced from cylindrical retorts was sold at 27 shillings per chaldron; and that produced from the elliptical retorts, at 22 shillings per chaldron: the breeze (or small coke) at 18 shillings per chaldron: the coal tar at £8 per ton: the ammoniacal liquor at 3*d.* per gallon; and the gas at 15 shillings for one thousand cubic feet.

As in bringing out our results, we have in each

case stated the quantity of coals used for making gas, and for heating the retorts, and the quantities of coke and breeze, of coal tar, of ammoniacal liquor, and of gas produced, the reader can put the prices to each, which may suit his particular locality, and following out the method we have pursued, he will come to such results as will be applicable to the particular gas work in which he may be interested, but which will vary with respect to those which we have advanced, in such proportion as the lower prices of coals and labour on the one hand, and the lower prices of the products on the other, may bear upon the question. As regards the expenses of replacing burnt-out retorts, and repairing fire-work, we are not aware that we need make any remark beyond this—that they must mainly depend upon the price at which retorts, fire-bricks, &c. can be delivered at the place where the repairs are called for, and therefore may be more or less than we have stated, according to such circumstances.

## CHAPTER VII.

## On the Hydraulic Main, Connecting, H, and Dip Pipes.

By the term "Hydraulic Main," as it is used in gas-light establishments, is understood a cast-iron cylinder or pipe of from twelve to fourteen inches in diameter, which is supported in a horizontal position, somewhat higher than the top of the bed of brick-work by which the retorts are inclosed, with the front of which it lies parallel. Its situation is shown at E, figure 1, Plate IX., and at E, figure 1, Plate X. Its use is to receive the "*dip pipes*" (a section of one of which is given at figure 1, Plate XXII.) through which the gas, as it is evolved from the retort, after pursuing its course through the "connecting pipe" (see figure 2, Plate XXII., and the "H pipe," figure 3 of the same plate) passes, together with a portion of tar and ammoniacal liquor (both in a state of vapour), first into the hydraulic main, and from thence the different gaseous products are conveyed to the washer or to the condenser. The diameter of the hydraulic main is different in different establishments; in small works it is sometimes not more than ten inches in diameter, in larger ones it is from twelve to fourteen, according to the number of retorts which may be worked into it. In works where from forty to

sixty retorts of any of the descriptions hitherto named work into one hydraulic main, it need not be more than twelve inches in diameter.

The hydraulic main is generally constructed of flanch pipes ; sometimes however it is made of a different shape (see transverse section, figure 4, Plate XXII.), in lengths of nine feet each. One end of it is closed by a blank flanch, so as to be perfectly gas tight. The other end is also closed by means of a cast iron flanch, with a hole cast in it (see figure 5, Plate XXII.), in such a position, that when it is jointed to the hydraulic main, and that is fixed in its place, the lowermost part of the hole cast therein shall be on a level with that at which the fluid in the hydraulic main is intended to be kept. It is desirable that semi-flanches of boiler plate should be placed between each of the different lengths of which the hydraulic main is formed, for the purpose of keeping the fluid it contains at its proper level in each length. The bottom of the hole in the exit end flanch and the tops of the semi-flanches just spoken of, should each be about two inches and a half above the line formed by the bottom of the dip pipes ; under such arrangement, the gas, as it is discharged from the retort, will always have to force its way through that depth of fluid before it can enter into the hydraulic main.

For explaining what end the dip pipes answer, we have given a section of the cylindrical hydraulic

main, showing one of them in its place (figure 6, Plate XXII.). The dip pipe is generally about two feet in length, and three inches diameter inside; at the top is a socket for receiving the H pipe of the same diameter. At about eight inches from the spigot end of the dip pipe is a circular saddle of about nine inches diameter, cast to the radius of the exterior surface of the hydraulic main. The hydraulic main is cast with holes at proper distances, for receiving such a number of dip pipes as there are retorts to work into it, which dip pipes are jointed upon it by means of iron or rust cement in the usual way. When the dip pipes are all jointed in their places, the range of the spigot ends of these pipes will equally descend into the hydraulic main, and of course, supposing the hydraulic main be placed so as to lie perfectly level, which it always ought to do, should one of the dip pipes be immersed to the depth of two inches and a half in any liquid that the hydraulic main may contain, each dip pipe of the range will be equally immersed.

Now, when it is considered that if there were not some contrivance for preventing the gas returning from the main pipes towards the retorts when the mouth pieces are removed during the operation of drawing and charging the retorts, either by stop-cocks, or valves upon each of the gas conducting pipes, or other means, the process of making gas would not only be attended with much waste of gas,

but it would also be attended with extreme danger ; for, as the gas would be passing over, by means of the conducting pipes (there being no hydraulic main, but merely a common receiving main for all these pipes), in a range of sixty retorts, from fifty-two of them, whilst eight were being drawn, it must follow that, without some contrivance for shutting off the gas then making from the open retorts, the gas then making from the fifty-two retorts would escape at the mouths of those retorts which had their lids removed, and burst forth with such a body of flame as could not be approached : indeed more serious consequences might ensue from the admission into the open retorts of atmospheric air.

The necessity for preventing such things happening is obvious, and a more simple, and at the same time safe, method than that of the hydraulic main and dip pipes could hardly have been devised : for had stop-cocks or valves been used, they would either have been attended with considerable trouble or ever liable to get out of order ; so much so, that no dependence could be placed upon them : for the tar and ammoniacal salts would in a short time so clog the plugs of the one and the spindles and sliding parts of the others as to render it a matter of great difficulty to move them.

It must be clear to every reader who may take the trouble to refer to Plate X., figure 3, that unless the pressure upon the hydraulic main from the

purifying vessel be greater than a vertical column of water equal to the distance between the bend part of the H pipe and the water level of the dip pipe in the hydraulic main, the gas, after having once entered the hydraulic main, cannot be forced back into the retort. In mentioning the pressure from the purifier (we refer, in speaking of it, to such as are constructed for purifying the gas by means of the cream of lime), it is to be understood that, whatever depth of lime in solution the gas, after entering the purifier, has to rise through before it can escape towards the gas-holder, is considered to be the pressure at which the purifier is worked. Thus, for instance, the most usual depth of the purifying mixture, when lime and water are used, through which the gas bubbles up in the process of purification, being ten inches in the purifying vessel, the purifier in such case is said to be worked at ten inches pressure. The length of the dip pipe has been stated at two feet: from the top of it to the bend part of the H pipe may be stated at six or eight inches, making together about two feet six inches; consequently, before the pressure in the purifier can be sufficient to force back the gas from the hydraulic main through the conducting pipes to the retorts undergoing the operation of drawing, it would require to be three times greater than what the wet lime purifier is usually worked at. But, as there is a possibility when the wet lime purifier is

used, and more particularly so if it be not exceedingly well constructed, of its being choked up, there ought to be some contrivance to indicate to the workmen when such happens to be the case, or when the pressure there was so considerably on the increase as to endanger the safety of the retorts. This might be accomplished by having a pressure gauge fixed in such a situation that it could always be consulted, or by means of a small bell, which might be made to ring from its detent being liberated by a striking rod attached to a piston working in a bored pipe, and which would be raised high enough to do so by any increased pressure of gas deemed dangerous acting under the piston, the whole contrivance bearing a strong resemblance to the alarum of a clock.

We have spoken of the wet lime purifier, because in many gas-works, notwithstanding the superiority of the dry lime purifier, it is still used. In the latter, the pressure seldom exceeds two or three inches, so that any inconvenient pressure upon the retorts or the hydraulic main is not very likely to occur when such mode of purification is followed. It is desirable, however, in this case also to have any stoppage between the retorts and the purifier indicated as soon as possible, for which purpose either a pressure gauge, or a bell, as already mentioned, is particularly applicable.

The hydraulic main, with the dip pipes, form a

series of hydraulic valves (or joints), than which, in the manufacture of an elastic fluid like coal gas, nothing could be so safe or so well adapted. Figure 7, Plate XXII., exhibits a longitudinal section of the hydraulic main and dip pipes; and figure 8 a front view of the same. It is of considerable importance that the hydraulic main should be constructed of pipes or castings of the best quality, that the joints should be sound, and the work altogether well turned out of hand; for an accidental derangement of its parts generally puts a stop to the production of gas, for obvious reasons. Previous to the retorts being brought into action, the hydraulic main must be filled to the height of the under side of the hole in the round flanch at the end of it already described with water, so that all the dip pipes may be sealed thereby. Before the retorts have been long in action, however, the water will be forced gradually through the hole in the end flanch, and its place will become occupied by the coal-tar and ammoniacal liquor which have been produced during the distillatory process. As the two latter are of greater specific gravity than the former, they will, as they accumulate, subside in the hydraulic main, and the water, being lighter than either, will be the first displaced therefrom.

Accidents have been heard of, occasioned by the gas in the hydraulic main forcing the glans from the top of the H pipes; but such accidents must

have arisen from great carelessness on the part of the operator, or from the clogging up of the purifier; for, by attending to the observations already made, as to the situation of the hydraulic main and the manner of putting it up, no accident of the kind can possibly happen.

It is from a very erroneous notion that some constructors of retort furnaces and their appendages, of which the hydraulic main is one, place the hydraulic main nearer to the mouths of the retorts than we have described: by its being so, the gas conducting pipes, by being brought more contiguous to the furnaces, so heat the tar on its way to the hydraulic main as to cause it to be converted into pitch before it can get there, which in a short time so completely fills the gas conducting pipes as entirely to stop the passage of the gas from the retorts. The consequences resulting therefrom are these,—the glans of the H pipes require to be removed, the joint of the retort-lid broken, and a loss of all the gas that may be generating from the retort till a man has been able, by pushing an iron bar heated at one end through the H pipe and down the gas conducting pipe, to clear away the pitch and open a passage for the gas, secure the joint between the glans and H pipe, re-lute and secure the retort-lid. Owing to the gas conducting pipes being of small diameter in the early stages of the gas manufacture, their choking up was of frequent occurrence; and

where there were forty retorts in action it was no uncommon thing to have as many pipes to clear in the course of twenty-four hours. The gas conducting pipes were then seldom more than two inches in diameter inside: for many years back, however, the diameter has been increased to three inches. These being made very slight, and being placed further from the fire-work, are not liable to be choked up. The action of the air upon their exterior keeps them cool enough to prevent the tar from adhering to their sides, as was the case when pipes of smaller diameter were used. When the pipes of three inches in diameter are used, such part of the tar as is therein condensed before it reaches the hydraulic main returns to the retort, where it is decomposed, and afterwards passes over with the gaseous products by which the proportion of gas obtained from a ton of coals is increased. In short, by increasing the diameter of the gas conducting pipes, which are but appendages to the hydraulic main, H, and dip pipes, their choking up is avoided, and, consequently, the gas, instead of being frequently wasted (as was the case when smaller sized gas conducting pipes were used), is increased, and the labour consequent upon the use of the smaller sized pipes avoided.

## CHAPTER VIII.

On the Washer, Condensing Main, and various other methods of Condensation.

GAS, as it is evolved, is mixed with tar and an ammoniacal fluid in a state of vapour, which pass over with it from the retort to the hydraulic main; it therefore becomes necessary that, *as much as possible*, these two products should be condensed and lodged in their proper reservoir before the gas reaches the purifier. In order that this condensation may be properly effected, the products generated should be exposed to a large surface of some cold body when on their passage to the purifier: by such means the tar and ammoniacal vapours are in a great measure precipitated, by the loss of their caloric, in a fluid state, and are so separated from the gas; and being of much greater density than the gas, subside and drain through the pipes to the vessels appropriated to their reception. When the gas is well cooled, it is much more fit for the lime in the purifier to act upon than if it were brought to the purifier directly from the hydraulic main in a hot state; for whenever it is so, it is impregnated with tar and other matters, which very soon render

the purifying medium (whether that be lime and water or moistened lime) useless, by depositing themselves thereon, and by that mixture preventing the gas from acting thereupon. The consequence of bringing the gas in a hot state to the purifier is, that a much greater portion of lime will be required for the purifying process, or otherwise the gas will pass through the purifier to the gas-holder hardly acted upon. The use of impure gas ought on all occasions to be avoided, for whenever it is used it is almost impossible to obtain a good light; when it is submitted to combustion, it smokes and emits a disagreeable odour; the plugs of the stop-cocks on the fittings become choked up with tar, which, however surprising the case may seem, has been found in situations distant a mile and a half from the manufactory, after the gas had passed through various pipes of different diameters and placed at different levels.

The great preventive against impure gas finding its way into the gas-holder is its being thoroughly condensed, or cooled, before it reaches the purifying vessel: on that almost as much depends as upon the purifying process which is there accomplished; for whether gas be purified by lime and water, by moistened lime, or by any other purifying medium, it is of the utmost importance that it should be deprived of the tar, ammonia, &c., which were generated at the same time as it was before it enters

the purifier ; and it may be considered as a general rule which the manufacturer ought ever to observe, let the mode of purification be what it may, never to submit his gas to the purifying process till it has been well condensed or cooled.

Experience having taught the manufacturer the necessity of attending to the subject of condensing or cooling the gas manufactured, he, of course, adopted such means as he considered most advisable for effecting that object. In some manufactories, it was thought that the gas would have been sufficiently condensed from its being conveyed from the hydraulic main by a pipe laid in a direct line from the retort-house to the purifier ; in others, the gas was conveyed to the purifier through a worm-pipe placed in the tank of the gas-holder ; and again, in others, by ranges of pipes laid parallel to each other at a considerable depth and with a certain declivity from one end of the works to the other ; whilst some, in addition to these contrivances, proposed a tank into which the ranges of pipes, as last specified, should convey the gas at the bottom, and, by means of a contrivance something similar to a shower-bath, cause the gas to be washed there before it could make its exit towards the purifier. Most, if not all, of these methods have been tried by different operators, and have been found more or less effective. The first could hardly be expected to answer, unless the distance from the retort-house to the purifier

had been much greater than is generally the case ; the others, possessing similar properties, produced results proportionably analogous to the length and temperature of the main through which the gas was conveyed. But all of these methods were expensive, and attended by inconveniences which it was of the utmost importance to avoid. By each of the methods spoken of, one very great evil sometimes occurred, that is to say, the condensing main became choked up by a deposition of ammoniacal salts. This was more frequent when the manufactory was extensive and the diameter of the condensing main was too small, as was sometimes the case formerly when the condensing pipes had been laid down without a proper inquiry having been first made as to the possible quantity of gas to be supplied, and, consequently, to be manufactured. Such an oversight as this, when the manufacture was, as it were, in its infancy, is not to be wondered at ; but now, when the mode of obtaining light by means of coal-gas has become so general, the managers of gas establishments generally know pretty nearly what number of lights they will have to furnish before they commence erecting their apparatus, consequently will guard against their power of condensation being too small, and will also take means to prevent any stoppage of the gas in the condensing main, or in the vessel appropriated to the condensing (or cooling) of the gas, so as to

preclude even a possibility of accident. Should the condensing main (where it is still used) or the condenser, however, become choked, the most serious consequences might ensue; for, whenever such is the case, the pressure upon the hydraulic main will accumulate to an alarming degree, so much so as to force the fluid it contains over the H pipes into the retorts, which will endanger the whole of them, by being rapidly converted into steam. Indeed their safety can only be effected by removing the lids from the mouth-pieces; an operation which, under such circumstances, it is no easy matter to perform. There are several objections against using condensing mains; first, the expense of laying them down is enormous; secondly, they fail to perform the process of condensation equally well with other methods of performing the same at one-third of the expense, and which are perfectly safe in their operation; and thirdly, they are much more likely to be choked up than the condensing vessels now generally used, and much more difficult to cleanse. Indeed there are so many objections against them that they ought never to be used in any gas manufactory.

It was not till the year 1817 that any other mode was used except that of passing the gas through a condensing main, for the purpose of cooling it, and partially depriving it of the tar and ammoniacal fluid which had come over along with it from the hydraulic main in a state of vapour.

In August of that year a condensing vessel, as described by figures 1, 2, 3, and 4, Plate XI., was brought before the notice of the public by Mr. John Perks, who in that month took out a patent for his invention. His condensing vessel consisted of a tank made of cast-iron plates with a bottom about twelve inches deep, divided into compartments, as shown in figures 4 and 5. Over this part of the vessel was placed a cast-iron cover, cast with holes in it in such situations that, when fixed in its place, two of such holes should fall or be directly over one of the compartments of the bottom (figure 2, Plate XI.). Over these holes were fixed cast-iron flanch pipes which were bolted down upon the plate (figure 2), and which are represented in figures 3 and 4. On consulting figure 4, it will be seen that the gas enters into this condensing vessel by the pipe marked 1, through which it descends into the compartment marked *i*, from whence it has no means of escaping (the bottom vessel being filled with some fluid to the height of the dotted line *a, b*) except by ascending through the pipe 2; it then passes through the bend *g*, and descends through the pipe 3 into the division marked *j*, rising from that compartment by the pipe 4, descending again by pipe 5 into the division *k*, and thence rising by the pipe 6; and thus descending and rising in the direction of the arrows shown upon figures 1 and 3, till it reaches the pipe nearest

to B in these figures, when it is carried away towards the purifier. The figures 1, 2, 3, and 4, in the plate, are drawn from a scale of one inch to three feet, so that the dimensions of the bottom are about six feet by four feet six inches, and the length of the upright pipes (forty-eight in number) about eight feet six inches each; these with the bends make a length of pipe for the gas to travel through of about 432 feet or 144 yards, notwithstanding the condenser stands upon so small a base. The tank surrounding the upright pipes is about ten feet in depth, and is, when the vessel is brought into action, to be filled with water as high as the top of the upright pipes, by which means the pipes are kept constantly cool, and the condensible products fall into the square recesses at the bottom, from whence, by a contrivance of the inventor, they are conveyed to their proper receivers. For making our explanation of this condenser more intelligible, we add, that *figure 1* is a plan of the top, showing the situation of the bend pipes, &c. *Figure 2* is a plan of the under side of the plate upon which the upright pipes are supported, showing the openings into the lower chambers and the plan or position of the upright partitions therein. *Figure 3* is a side view (in elevation) of the condensing vessel, the side plates being supposed to be removed. The pipes E and E and the bend beneath are for carrying off the condensations. The dotted lines *a*, *b*,

show the height at which the fluid in the bottom will be constantly kept in that part of the vessel. An opening is made or left at the bottom of each partition which divides the lower vessel, allowing the condensed matter to flow from one compartment to another, and to be carried off by the pipe E. *Figure 4* is an end view of the condensing vessel (in elevation), the end plates being supposed to be removed.

About the same period as that we are now speaking of, as was mentioned in the former editions of this work, a condensing vessel, different in construction and principle from the above, was invented by Mr. John Malam, which has recently been adopted by several gas companies, and is reported to be very effective in its operation. The condenser just alluded to, as proposed by Mr. Malam, is a vessel constructed of cast iron plates about nine feet long, five feet wide, and four feet deep. Into this vessel he introduces cast iron plates, at distances of from six to eight inches from each other, with raised edges of about three inches in height; these he bolts to the sides of the vessel, perfectly parallel to each other; they are in length about eight feet six inches, so that being secured to the sides of the vessel and to one end of it, the other end of the plate remains at the distance of about six inches from the opposite end of the vessel. The lowermost of these plates being connected to one end of the vessel, the next plate above

it is connected to the opposite end, the third plate to the same end as the first, the fourth to the same end as the second, and so on alternately till all the plates are fixed. This being done, preparatory to bringing the condenser into action, water is introduced at the top (through the hole over which the exit pipe is to be afterwards fixed), which fills the uppermost shelf to the height which the projecting part of it allows; the water then runs over and fills the second, from thence the third is filled, and so on until the whole range are so. From considering this matter, it is evident, if the entrance pipe be at the bottom of the vessel to the right, should gas be introduced therein by its means, it will pass over a sheet of water equal to the area of the lower shelf, and as the next shelf above approaches no nearer to the end towards the left than six inches, it will, by that opening, rise above it and pass towards the right, where it will again find an opening at the end of the third shelf, and so it will pass alternately to right and left till it reaches the exit pipe above the top shelf of the vessel. The condensible products find their way from the top shelf to the bottom of the condenser, whence they are carried off towards the tar cistern, by means of the pipe F, of figure 8, Plate XI., which figure represents a longitudinal vertical section of a condenser, similar to the one which we have been describing: A B top plate or cover, CD bottom plate, E gas entrance pipe, G gas exit

pipe. A condenser of this kind may be recommended to the notice of the manufacturer, inasmuch as its first cost will be moderate, its durability may be depended upon, and its action is certain.

In considering the two modes of condensation last mentioned, we cannot fail to observe the facility they afford for removing any obstruction, and their efficiency for answering the purpose of the gas manufacturer, so far as relates to the gas generated being well condensed and cooled before it is allowed to enter into the purifier. We have already stated the distance the gas would have to travel in passing through such a condenser as is described in Plate XI., figures 1, 2, 3, and 4; and if we suppose the upright pipes to be always surrounded by *cold* water, the effect must evidently be very superior to the old mode, or condensing main. Various modifications of this condenser are in use up to the present time; but are now generally without that part of the tank which surrounds the upright pipes, it being considered by many that on the outer surface of the pipes the air alone will sufficiently cool the gas. Such condensers generally resemble figures 3 and 4, Plate XI., without the upper tank, the lower one remaining as there shown, and divided into compartments as exhibited in the plan, figure 2 of the same plate. Others again construct the upper part of their condensers of boiler plate, formed into square pipes by riveting (see plate XII., figures 1 and 2), the tank in which the con-

densing pipes stand being open at the top, and the products of condensation deposited therein being carried therefrom towards the tar cistern by means of the pipe J. Circular pipes, however, are not the best formed for cooling the gas, for when gas passes through such, that which is near the centre will be but little acted upon, if at all, by the cold body by which they may be surrounded—it is therefore always better that the gas should present itself to the cooling medium in very thin sheets, in order that every part of it may equally be acted upon by the adjoining cold surfaces; by such means a thorough condensation (or cooling) of the gas will be more certainly effected. In the condenser, figures 1, 2, 3, and 4, Plate XI., the bends at the top are easily removed in the event of any obstruction presenting itself, when, by forcing down each of the pipes a rod kept ready for the purpose, the passages may be easily cleared, the obstructing matter will fall down into the lower vessel, and as there is a sufficient opening left there at the bottom of each of the partitions, such obstructing matter can be withdrawn from thence. In the ends of the condenser, figure 8, Plate XI., there are circular openings opposite each of the gas ways, each covered by a lid, and made gas tight by means of screws and a pasteboard joint, when the vessel is in action, but which lids can be removed, should there be any stoppage, and the salts or other obstructing matter can be drawn out through the

said holes, and when that is done, the lids can be re-secured in their places as before.

A B C D, *figure 5, Plate XI.* is a longitudinal vertical section of another condenser, which is drawn from a scale of five-eighths of an inch to a foot. It is made of cast iron plates, and rests upon a bed of brick-work, as shown in the figure. At about one foot from the bottom is a range of plates, *a a a*, together, of the same size as the bottom, and which are jointed to the vessel. Upon these stand rows of cast iron plates, one of which is shown at E. Their lower edges occupy such situation as is shown in the plan A B C D, *figure 6.* In that plan, the pipe which conveys the gas into the condenser is shown at E; it then passes between the upright plates in the direction of the arrows, till it reaches the exit pipe F, and that pipe leads toward the purifying apparatus. It is to be noticed, that these upright plates do not rise to the top of the condenser, there is a space of about six inches left between the top and the plates which fit over them. The entrance and exit pipes E and F are placed about one foot from the top of the vessel, as shown in the transverse vertical section, *figure 7.* The range of cast iron plates *a a a a*, already mentioned, do not lie perfectly horizontal, but with a small declivity to the right, by which arrangement the condensed matter drains towards the openings *a, b, c, figure 6,* and thence by the pipe *a, figure 5,* and *a, b, c, figure 7,* is discharged into the receptacle

E, which is carried across the vessel, and is filled with water for the pipes *a b c* to dip in, and form an hydraulic joint. It follows therefore, that as the condensable products accumulate, they flow over the partition which forms the part E, and run into the chamber G, from whence, when it is necessary, they may be drawn off by the cock H, *figures 5 and 6*. A, B, C, D is a plan of this condenser, the arrangement of which is already described, and *figure 7* is a transverse vertical section of the same vessel.

Before we conclude this chapter, we propose to describe two more condensers, one of which is applicable to small works, the other, according to its size, will answer well for gas-works of any magnitude ; but before we do so, we propose to make a few observations relative to a vessel used at some gas-establishments by which the gas is made to pass through a fluid before it enters the condenser, which causes it to be deprived of an additional portion of the tar and ammoniacal fluid which had come over with it from the hydraulic main. The vessel we are speaking of is called in gas-manufactories "*The Washer*." We now proceed to describe it. ABCD, *figure 9*, Plate XI., is a plan of the top of the washer, and *figure 10* of the same plate is a longitudinal vertical section thereof. The figures 9 and 10 are drawn from a scale of a quarter of an inch to a foot. The vessel is constructed of cast-iron plates, and one of such size as is given in the figures is

sufficiently large for an establishment where about twelve elliptical retorts are worked at one time. The washer is fixed underground and connected by the pipe E to the pipe which brings the gas from the hydraulic main. Before bringing it into use, it is filled with water as high as the dotted lines *eeff*, figure 10, consequently the whole of the bottom marked \* is filled with water also : it therefore follows, as a natural consequence, that the gas which enters the washer by the pipe E finds its way into the space marked G, from which it cannot escape except by passing through the water below *ee* and *ff*, and through the space also filled with water at \* : this it effects ; and having entered the chamber H, it is from thence conveyed by the pipe F towards the condenser. On noticing *figure 10*, it will be observed that one end of the washer is placed two or three inches lower than the other. At the lower end, at *e*, a pipe is fixed which leads towards the tar cistern, where it dips into a pipe filled with water so as to form an hydraulic joint in the usual way (as described in *figure 3*, Plate XII.) Whilst the washer contains water only, the gas passing through it is cleansed to a considerable extent ; but the place of the water, very soon after the washer has been in use, becomes occupied by tar and ammoniacal liquor, and when it is so, it answers no very useful purpose, as the mixture the gas has to pass through in the washer much resembles what

has by that time been deposited in the hydraulic main. The use of it is not at all recommended, from its augmenting also the pressure on the water in the hydraulic main, and it is spoken of here only from its being occasionally used.

A condenser which will answer for a gas-work where only two or three retorts are used is exhibited in Plate XII., *figures 1 and 2*, which figures are drawn from a scale of a quarter of an inch to a foot. *Figure 1* is a longitudinal vertical section of this condenser, in which *GHIJ* represents a trough made of boiler-plate riveted together, in which the pipes *BCDE* stand, which are also made of boiler-plate riveted together, open at the bottom and closed at the top by means of a flanch. The upright pipes *BCDE* are connected together by the flanch sockets *a, b, c*. The tank *GHIJ* being nearly filled with water, it is evident, from examining *figure 1*, that if the gas be introduced into the condenser by the pipe *A*, it will descend down *B*, and through the double socket *a*, into the pipe *C*, which it will ascend; from thence it will proceed through the double socket *b* into the pipe *D*, descending down that to the double socket *c*, through which it will pass into the pipe *E*, and thence through the exit pipe *F* towards the purifier. The pipes *BCDE* are hollowed out at the bottom, in order that whatever may be condensed in them, as the gas passes, may be deposited in the

trough G H I J, from which it may be drawn by a cock placed at a proper level, as shown in *figures 5 and 6, Plate XI.*, or carried off by a pipe to the tar cistern, as may be most convenient. *Figure 2* is a plan of the trough and of the condensing pipes B C D E, showing also the entrance pipe A and the exit pipe F.

Plate XII., *figure 3*, is a longitudinal vertical section of a condenser, A B E F, with a tar cistern below it, E F C D: this figure and figure 4 are drawn from a scale of a quarter of an inch to a foot; we propose in this place to describe the condenser only. It is made altogether of cast-iron plates: E F is the bottom of the condenser. In it are placed two tiers of plates, with an inclination, as shown in the figure marked *a* and *b*. The lower range of the lowermost tier is cast so as to form a trough, *c*, which extends to the entire width of the plates *a* and *b* when put together. When the plates marked *b* are fixed in their places, the width of the condenser is divided into a number of long, narrow gas ways by the partitions marked *d d*, which are shown in section by *figure 5*, and in plan by *figure 6*; both drawn from a scale of three inches to a foot. These partitions are about six inches shorter than the entire length of the condenser, consequently when fixed they alternately fall so much short of the ends of the condenser, as better seen at *figure 4*, in which the direction the gas takes is

pointed out by arrows. Those which are brought close to the end *A E* are about four inches deeper at that end than in the other part, in order that they may dip into the trough *c*, which is constantly filled with a fluid. This trough receives all the products of condensation which are carried off by the pipe *g*, shown therein, into the tar cistern *H*. When the partition plates *d d* are all fixed in their places, and the pipe *g* secured to its situation in the trough (the pipe into which it dips, *h h*, being first fixed in its place and filled with water, as must also be the trough *c*), the upper range of plates *a* are laid upon the partition plates and screwed down to them by means of bolts passing through the plates *b* and the partition plate *d*, through the hole shown in figure 5, three such being cast in each partition plate. When this is done, the top plates are jointed together in the usual way, as are also the side plates *h h* (*figure 4*). This being done, the condenser itself, *ijkl* (*figure 4*), will be completely closed, and then the tank *ABEF* may be filled with water. The orifice *e* in this figure represents the pipe which brings the gas into the condenser. *Figure 4* is a plan of the condenser, showing the condensing part, *ijkl*, which is not so wide as the tank *IJAB* by about twelve inches. *e* is the situation of the pipe which brings the gas into the condenser; it then passes in the direction of the arrows between the partition plates *d d d*, till it

comes to *f*, which is the situation of the exit pipe, and from which the gas passes towards the purifier. The condensable products fall into the trough *c c c c*, which, when full, runs over the pipe whose situation is marked at *g*, by which they are conveyed into the tar cistern H. *Figure 5* is a plan of part of one of the partition plates, and *figure 6* is a section of the same: these two figures are drawn from a scale of three inches to a foot. *Figure 7* exhibits a part of one of the end plates of the condenser, drawn from a scale of one inch to a foot. The holes 4, 5, and 6, are opposite the gas ways numbered 4, 5, 6, in figure 4, and are for the purpose of clearing away any salts, &c., that may accumulate in the condenser. The three holes opposite the gas-ways 1, 2, 3, figure 4, are shown as covered by a lid which can be easily removed, should it be needful, at any time, to examine the internal state of the condenser; and they can be very quickly replaced. The mode of securing these lids is shown at *figure 8*, which is drawn from a scale of three inches to a foot. In this figure, *a a a* represents a bolt which may be made with a quick square-thread screw; this bolt must be of sufficient length to pass through the lid *d d*, the pasteboard flanch *e e*, the thickness of the end plate of the condenser *f f*, and the cross piece *b b*, which will enter inside the end plate, as at *b b*, figure 7. *c c c c* are the openings which correspond with those marked 4, 5, 6, figure 7. It

is evident that when the pasteboard flanch is placed upon the inner face of the lid, and the cross bar passed through the openings *b b*, by its being moved a little to the right or left of these openings, it will lay hold of the inside of the end plate of the condenser, and, consequently, may be screwed up by means of the bolt *a*, so as to form a perfectly secure joint. In the condenser described by figures 3 and 4, Plate XII., there are twelve holes at each end corresponding with the gas-ways, and three of these are covered with one lid, so that there are four lids at each end. When removed, an iron rake can be introduced through them, by which means all condensed matters can be extracted; and, as the workmen can see from one end of the gas-way to another, they can be certain of all impediments being removed before the lids are refixed. In a condenser of the size shown in the plate, the whole operation of taking off the lids, cleaning out the condenser, and refixing the lids, can be performed by a couple of workmen in three or four hours. This description of condenser I think well adapted for any gas work, from having used such for several years, during which period they never created any trouble from stoppage or otherwise, and they were found very effective in their operations.

## CHAPTER IX.

On the Situation and Construction of Vessels for receiving the Tar and Ammoniacal Liquor.

As every ton of coal when submitted to distillation in close vessels for the purpose of collecting the gas evolved, and its other products, produces from 1 to  $1\frac{1}{4}$  cwt. of coal tar, and from eleven to thirteen imperial gallons of ammoniacal liquor, it becomes necessary that they should be received into some vessel after they leave the hydraulic main, otherwise they would soon fill the line of pipes between the hydraulic main and the purifier, and consequently stop the process. To prevent this, a cast iron pipe is sometimes connected to one end of the hydraulic main, distinct from that pipe which leads to the washer or condenser, and which has a declivity towards the vessel appropriated for receiving the condensable products. This vessel is called the "Tar Cistern," or "Tar Well." The tar cistern ought always to be placed between the condenser and the purifier, in order that condensation may be properly effected before the tar and ammoniacal liquor are allowed to enter it. In most cases, the tar cistern is so situated as not to receive the tar and ammoniacal liquor till they have with the gas passed through the

condenser. Under such arrangement there is but one connexion to the hydraulic main, (instead of two,) which conveys away from it all the products evolved, and all pass together to be condensed ; after which process the pipes are so arranged as to allow the tar and ammoniacal liquor to be carried into the tar cistern, and the gas to enter into the purifier. In this case the top of the tar cistern must be situated below the level of the bottom of the condenser and purifier, otherwise the pipes between it and the condenser, and also between it and the purifier, would soon be filled with tar.

The tar cistern may be made of any convenient shape, and constructed of cast iron plates, or of brick or stone well puddled under the bottom and round the sides, so as to prevent any leakage. In all cases it ought to be closed at the top, with the exception of a very small aperture to prevent the ammoniacal liquor losing its strength from exposure to the air.

To prevent the gas from entering into the tar cistern, the pipe which brings the tar and ammoniacal liquor into it descends through the top of it nearly to the bottom inside. This pipe is received into another of two or three inches greater diameter, cast with a flanch at one end, upon which a blank flanch is jointed. The larger pipe is put upright into the tar cistern before the one which brings the tar and ammoniacal liquor into it is fixed so as to stand upon the closed end ; it is then filled with water, and the

first named pipe is dropped into it so as to have a dip of two or three feet. With such dip no gas can escape ; for when the distillatory process commences, the tar and ammoniacal liquor drain down the inner pipe, and the outer one being already filled, they run over the top of it and are deposited in the tar cistern, whilst the escape of gas into it is prevented by the dip already mentioned.

When the tar cistern is constructed of cast iron plates, it can be made either circular, oblong, or square, as may be most convenient. The one shown in figure 3, Plate XII., (under the condenser,) is about twelve feet long, seven feet six inches wide, and six feet deep. Such size was found to be sufficiently capacious where twenty small D retorts were constantly worked during the winter months, and a proportionate number during the months of summer. It was furnished with a cock at one end for drawing off the tar and ammoniacal liquor, which would draw off either one or the other as was desired. This was effected by means of a pipe inside the tar cistern of about six feet in length, which was attached to the cock inside the vessel, and by means of a moveable joint could be raised or depressed so that its upper end could be raised by a pulley and chain so as to be surrounded by the ammoniacal liquor, or depressed so as to dip into the tar : in one case allowing tar, and in the other ammoniacal liquor, to issue from the cock when opened. C, D, E, F, figure 3, Plate XII.

is a longitudinal vertical section of a cast iron tar cistern, resting upon a base of stone or brick-work about fifteen inches in height. At the end near C E is placed a pipe \*\* closed at the bottom and filled with water, into which dips the pipe *o*, which brings the tar and ammoniacal liquor into it from the condenser; and, by a similar arrangement, the tar and ammoniacal liquor which are brought direct (by means of a separate pipe) from the hydraulic main enter into the tar cistern also.

When it is deemed expedient to make a tar cistern under ground of masonry or brick-work, it ought always to be circular in its plan, and with an inverted dome for its bottom, as shown in figure 9, Plate XII., which is the vertical section of a tar cistern, about nine feet deep, and eight feet in diameter, at the widest part. In a tar cistern of that size, the ground having been excavated, and a thickness of about eighteen inches of well tempered clay laid over the bottom, let the stone *f* be fixed, against which let the inverted arch be built of brick, laid in Roman cement, puddling well at the back of the said brick-work about one foot in thickness at one time. Afterwards carry up the perpendicular part of the work, and when that is done, finish the upper part or dome upon proper centering, leaving a circular opening as *a a* at the top for bringing the tar pipes into it, which opening can be covered with a flag stone when the brick-work, puddling, and filling in are completely finished

and the tar pipes fixed in their places. Only one tar pipe *b*, and one dip receiving pipe *c c*, are shown. It is supposed to be brought directly from the hydraulic main, the other dip and receiving pipe would bring the tar and ammoniacal liquor from the washer and condenser, but being precisely similar to the one shown in the figure, it need not be further dwelt upon. The tar or ammoniacal liquor can be pumped out of this tar cistern at pleasure, by a pump fitted with a moveable suction pipe working at its joint in a stuffing box. This suction pipe can be raised so that its extreme end shall be in the ammoniacal liquor, which, being of less specific gravity than the coal tar, always occupies the uppermost part in the tar cistern. The suction pipe is raised by having a chain attached to it which comes through the top of the tar cistern, and is then secured to a barrel fixed in a frame (with a pall at one end of it) which is turned by a winch, so that when fixed at any particular height it will remain stationary, and the pump may be worked till the ammoniacal liquor is lowered beneath the end of the suction pipe, when the pall may be disengaged and the pipe again lowered and the pumping continued. When it is desired to obtain tar, the best way to proceed is by turning the winch upon the barrel the reverse way to what had been done when ammoniacal liquor was wanted; this will allow the end of the suction pipe to fall nearly to the bottom of the tar cistern, where the thickest portion of the tar is

deposited. When it is in that situation, if the pump be worked, the tar raised by it will be of the best quality which the cistern contains, and more free from ammoniacal liquor than if pumped from near the surface. *Figure 9, Plate XII.* exhibits a brick tar cistern, drawn from a scale of a quarter of an inch to a foot. It will be quite large enough for a gas work where from six to nine elliptical retorts are worked at an average throughout the year. In it *a a* is the top opening already noticed, *b* the tar pipe, *c c* the receiving pipe for sealing the tar pipe *b*, *d d* fourteen inch brick-work laid in Roman cement, *e e* puddle at the back of the brick-work, which is to be put in about one foot in thickness at one time, great care being taken that the clay of which the puddling is formed be well tempered before it is laid in its place, and well wetted and trampled upon after it is there: for on the goodness of the puddle the soundness of the tar cistern depends, more than upon the execution of the brick-work. It is of the utmost importance that the tar cistern should be quite tight, not only on account of preventing waste of the tar and ammoniacal liquor it may receive, but also to prevent an escape of either of these fluids, which would percolate through the ground, particularly if of a gravelly nature, and, if by such means it found its way into any adjacent spring or well, would soon render the water unfit for use.

## CHAPTER X.

On the Purifiers used in the Coal Gas Manufactory, and the best mode of purifying Coal Gas.

DURING the process of decomposing coals in close vessels, it is found that on their being heated to a certain degree, a part of the carbon of which they are formed unites with a part of the oxygen, and produces carbonic acid gas. Whilst this process is going on, a part of the hydrogen of the coal is combined with another portion of carbon and caloric, which forms carburetted hydrogen gas. Olefiant gas, or bi-carburetted hydrogen, carbonic oxide, hydrogen, and sulphuretted hydrogen are also produced. Every kind of coal gas is a mechanical mixture of all these gases, and as the component parts of the coal submitted to distillation vary, so will the quantities of the gaseous products above named (carburetted and bi-carburetted hydrogen being the principal) vary also.

When the gas produced from coal is burnt without being purified, (that is, without being deprived of the sulphuretted hydrogen, and carbonic acid gas which it contains,) or if it be not properly purified, it throws out sparks, and produces sulphurous acid, owing to the oxygen of the air uniting with the sul-

phur burnt with the gas. Such gas sends forth a suffocating odour that is highly offensive and injurious to health. Where it is burnt, the levity of the odour arising thence carries it to the uppermost part of the room, and there it is easily perceived. It tarnishes all metallic substances, and discolours paintings in the execution of which metallic oxides may have been used.

The general way of freeing coal gas from sulphuretted hydrogen and carbonic acid gas, and rendering it fit for use, has been either by passing it through lime and water mechanically mixed so as to be of the consistence of cream, or by making it percolate through layers of slaked lime, so wetted before it is put into the purifier that, on handling it, it will not soil the fingers, as will be more fully shown hereafter, when describing what is generally denominated the dry lime purifier in contradistinction to the wet lime purifier; by some modification of one or of the other of which purifiers almost all the gas made at the present day is purified. It may also be purified by passing it through very dilute solutions of sub-acetate of lead, green sulphate of iron, or chloride of lime.

For the purification of coal gas when it is manufactured in the large way, various methods have been adopted; but they have all given way to one or the other of the two which we have named; that is to say, either to that by lime and water mixed to the consistence of cream, or to that by slaked lime

thoroughly damped. Besides these modes, purifiers have been constructed by which the gas was acted upon by lime in a semi-fluid state: others proposed to effect the purification by passing the gas through red hot cylinders filled with clippings of iron: others used a compound of lime with pot or pearl-ashes and charcoal or coke, which was formed by pouring a strongly impregnated solution of pot or pearl-ashes in water, upon recently burnt and unslaked lime; the quantity of the solution required being so much as would slake the lime, or cause it to fall to powder. This being done, dry pot or pearl-ashes were added to about one-fifth of the whole weight of the lime, and also about one-fourth of the bulk of the lime, of charcoal, or coke broken into small pieces; the whole was perfectly mixed together, and when so, formed the absorbent or purifying stratum. The apparatus which was used was enclosed within a square box or case internally divided into compartments by an endless web of wire-gauze, upon which the purifying mixture was spread. The web was extended upon cylindrical rollers, which were acted upon by machinery, and by which the abstraction and renewal of material were effected. The whole of the contrivance was of a very complex description, and not a whit the more efficient than the present ones in general use. Some again proposed to purify the gas in the retort where it was generated. We advert to these as some of the methods which have

from time to time been proposed to the attention of the public, but which we need not dwell upon further in this place, our object being rather to describe what has been generally proved and acknowledged to be useful, than to take up the reader's time in describing apparatus which have failed to be so.

We may here however remark, that when coal gas was first employed for the purpose of procuring light, it was allowed to proceed to the place where it was intended to be burnt without undergoing any purifying process other than passing it through water, and it appears that some time elapsed before lime and water were used as a purifying medium. For several years after lime mixed with water was used for the purpose of purifying coal gas, the operation was performed by means of a cast-iron square or cylindrical vessel, enclosing another vessel of the same shape, but of smaller dimensions, which was secured inside to the top of the outer one in such a manner as to be perfectly gas tight. The inner vessel had no bottom, and the sides of it were drilled full of holes to the height of six inches from the lower edge.

When such a purifier as we are speaking of was circular in shape, an upright shaft rested upon a step in the bottom, and was brought through a stuffing box at the top. At the head of the shaft was fixed a horizontal bevel wheel, to be driven by a pinion on one end of a shaft, to which the winch to be turned

by hand was applied at the other. The speed at which the upright shaft was driven was about ten revolutions in a minute. At the lower end of the shaft, and at a distance of four or five inches from the bottom of the purifier, were fixed four or more vanes, each of which was in length about three inches less than the semi-diameter of the outer vessel, and in breadth about four inches. Their use was to stir up the lime and keep it from subsiding. This was effected by a man turning the winch already mentioned, which gave motion to the pinion, consequently to the horizontal bevel wheel fixed upon the shaft, with its shaft and the vanes (or, as the gas light manufacturer terms them, "the agitators") thereunto attached.

In using this description of purifier it was necessary that there should be a vessel of sufficient capacity for mixing a sufficient quantity of lime and water for one charge, situated at such a height as would allow it to be turned, by means of a cock or valve, into the purifier, whenever it was necessary to introduce a new charge into it. This vessel was required to be fitted with agitators similar to those in the purifier, so that the mixture might be properly effected before it was allowed to enter into the purifying vessel. The admission of the mixture into the purifier was accomplished by means of a small vessel attached to the outside of it, the top thereof rising to the same height as that to which

it was desired the mixture should rise inside the purifier. Between this vessel and the purifier was a slide valve, opened for the purpose of charging the purifier, but kept closed when it was in action. Previous to introducing a new charge of clean lime and water into the purifier, the impure mixture had to be drawn off by means of a vessel and valve nearly similar to that shown at Q, figure 1, Plate XIII., the action of which will be fully described when we come to speak of the triple wet lime purifier. We will only here remark, that it must be evident that so soon as the impure matter was drawn off in a single purifier such as we have been speaking of, below the perforated openings in the inner cylinder, as already mentioned, till those openings were again completely covered by the new charge, all the gas made would pass into the gas-holder in an impure state, thus deteriorating the quality of the whole stock of that article.

Having mentioned the manner of charging and discharging the purifying vessel, we are next to consider how the gas is brought into it, acted upon therein, and allowed to pass thence into the gas-holder. In a preceding chapter, when speaking of the condenser, we described how the gas passes from the retorts towards it, and from the condenser to the purifier. In such a purifier as we are now speaking of, it was introduced at the top into the interior chamber which we have described. And

as the purifying mixture, when the purifier was charged, ascended to a height of about eleven inches above the lower edge of the interior vessel, it is evident that the gas accumulated therein till the capacity of the vessel became too small for its bulk, which continually increased till the gas forced its way beneath the inner vessel and through the holes in its vertical sides, and bubbled up through the purifying mixture into the space unoccupied by the lime and water in the outer vessel; from which, by means of pipes properly arranged, it was conveyed to the gas-holder. It is evident, then, that no gas could pass from the retorts to the gas-holder without first having passed through the purifier, and (except during the time employed in removing an old charge of lime and water and replacing it by a new one) it must pass through the purifying mixture also, which mixture being constantly kept agitated, so acted upon the crude gas, by the laws of chemical affinity, as to take up the sulphuretted hydrogen gas, &c., and to allow the carburetted hydrogen gas nearly free from such impurities to pass to the gas-holder.

What has been stated relative to the cylindrical purifier is applicable to the square one. In some establishments the purifier was formerly of rectangular base; and when so, it was furnished with two upright shafts and with double sets of agitators. But either of the latter shaped vessels are less ser-

viceable than the former ; for in them the angular points cannot be affected by the agitators, and, consequently, a considerable portion of the charge is lost to the manufacturer : this cannot happen to him when the cylindrical purifier is used ; for in it every part of the mixture is kept constantly agitated and is brought into use.

Purifiers of the description spoken of were all single vessels, and therefore, for reasons already given, not thoroughly effective ; in addition to which, the greater proportion of gas being generated during the first period of distillation, it would be more acted upon than that which was evolved during the latter part of the process, when the purifying mixture had become saturated with sulphureous particles. In consequence of this, it has been thought expedient to employ a series of purifiers : the one nearest to the condenser receives the gas in its most impure state ; after passing through it, it enters into a second, where it is again submitted to the purifying process, and so on, through any number of vessels, but which, in practice, never exceeds three. Under this arrangement, so soon as the gas is found to give evidence of impurity by the application of a proper test, the impure mixture should be drawn from the first purifier, and the purifying mixture contained in the second allowed, by means of proper pipes and valves, to be conveyed into it ; and the purifying mixture in the third, by

similar means, brought into the second ; after which there should be introduced into the third a fresh or new charge of clean purifying mixture. By these means the gas could never find its way into the gas-holder (as when single vessels were used) without undergoing the purifying process to a considerable extent. By it, also, the last vessel of the series, provided proper care were taken, would never become foul inside, as was the case when single purifiers were used. For the reasons we have given, as well as from much experience, we are decidedly of opinion, that when wet lime purifiers are used, however small the establishment may be, more than one should be employed, whenever the purity of the gas is of the least importance. In large works, more than one becomes a matter of absolute necessity. We are, therefore, to inquire which is the best arrangement for placing two, three, or more wet lime purifiers so that they may be the most effective in their operations, and at the same time the most economical as regards the cost of constructing and that of working them. The best arrangement for wet lime purifiers which has fallen under my notice, as well as the best construction of the purifier itself, were effected some years ago by Mr. John Malam, of Hull, (at the time when he was employed at the Westminster gas-works). It is shown in section and plan, figures 1 and 2, Plate XIII., which are drawn from a scale of a quarter

of an inch to a foot. *A B C D*, *figure 1*, is a vertical section of a treble purifier, placed upon a foundation of brick-work, and *figure 2* is a plan thereof. *E E*, *F F*, *G G*, *figure 1*, are sections of the three interior chambers bolted to the tops of their respective vessels by the flanches expressed in the plate. It will be observed, that the bottoms of these chambers branch out into a kind of broad flanch, by which means the gas is acted upon by a greater portion of the purifying mixture than if the vertical sides had no such appendage. *H* is the axis or shaft, upon which the agitators *I I* are fixed. *K K K* are three cylindrical vessels for the purpose of charging the respective divisions of the purifier, into which the purifying mixture is introduced by the bend pipes *L L L*. *M M M* are the pipes which convey the gas into the interior chambers. *N* is the pipe which conveys the purified gas to the gas-holder after it has passed through the three series or compartments of the purifier. *O* is the feed pipe for bringing the purifying mixture from the vessel where it is prepared into the purifying apparatus. *P P P* exhibit the openings near the bottoms of the cylindrical vessels *K K K*, for emptying the respective vessels or compartments of the purifier, which is effected by the slide valves, or cocks, *Q Q Q*. In this figure the height to which the purifying mixture rises is shown in the two lower vessels; but the upper one is exhibited as not

charged. The agitators are driven by hand, or other power, in the same way as has been already described when we were speaking of the single purifier.

When this purifier is first brought into action, the purifying mixture is turned into the uppermost of the vessels marked K, from whence it enters into the uppermost purifier by the bend L, till it rises to the height of the uppermost edge of the vessel K. When such is the case, by opening the uppermost of the slide cocks, Q, that charge is emptied from the first into the second vessel, which being done, the uppermost purifier is again charged. The middle cock, Q, is then opened, which allows the charge in the second purifier to enter into the lowermost one ; and whilst this is performing, that in the uppermost one is emptied into the second. The mixture is at the same time entering into the uppermost one, which is known to be properly charged when the mixture rises to the top of its supplying vessel K. This being performed, the gas in its crude state is allowed to enter into the interior chamber of the lowermost purifier by the pipe M, which being filled, it flows under the flanch part of it, and through the purifying mixture, into the outer part of that vessel marked R R, which is unoccupied by the purifying mixture : from thence, by the next pipe M, it is conveyed into the interior chamber of the middle purifier, where the action is

the same as in the lower one; and thence, by the uppermost pipe M, it is conveyed into the highest vessel, where, after having again undergone the purifying process, it is allowed to enter the gas-holder by the pipe N.

On examining the figures 1 and 2, Plate XIII., it must appear obvious, that the gas enters into the lowermost purifier in its most impure state; whence, after having been acted upon therein, it rises into the second in a purer state, and from thence into the top one. Under such circumstances, it follows that the charge in the lowermost vessel is rendered useless first: on its being so, it is drawn off by opening the bottom cock, Q; whilst this is being done, the gas generated has to pass through two purifying vessels before it can enter the gas-holder; but, in the single purifier, as has before been noticed, during the time of charging, the gas passes into the gas-holder in an impure state; thus, by mixture with the pure gas, deteriorating its quality. The bottom purifier being emptied, the mixture in the second is turned into it, and that in the top one into the second when the top one is to be recharged. The lowermost vessel, consequently, always contains the mixture which is most acted upon by the gas in its impure state.

By placing the purifiers one over another, a considerable saving in the expense of erecting them is effected, inasmuch as the top of the lowermost vessel

answers as a bottom to the one immediately above it, whilst the top of the middle vessel becomes the bottom of the uppermost one. The savings are not derived thence alone, for when they are placed separately, there must be a considerable outlay incurred for extra foundations, for pipes, and for machinery for driving the agitators, which would all be saved by adopting the triple purifier. Notwithstanding what has just been remarked, even where the saving of room is of great importance, the placing a series of single purifiers, apart from each other and at different levels, has been, and still is, a very prevailing system in those manufactories where wet lime is used for purifying the gas.

To give further details relative to the means of purifying coal-gas by passing it through a mixture of lime and water held mechanically in solution is quite unnecessary; for, although different operators may employ different shaped vessels for the purpose, yet they all must allow the gas to pass through a sufficient column of the purifying mixture to render the purification as complete as the wet lime process will make it; and, provided that be effected, the manufacturer's object is attained.

Our next business will be to notice the system of purification by what is called, though improperly, yet in contradistinction to the preceding system, "*The Dry Lime Purifier*." Mr. Reuben Phillips, of Exeter, was the first person who obtained a patent

Fig. 1

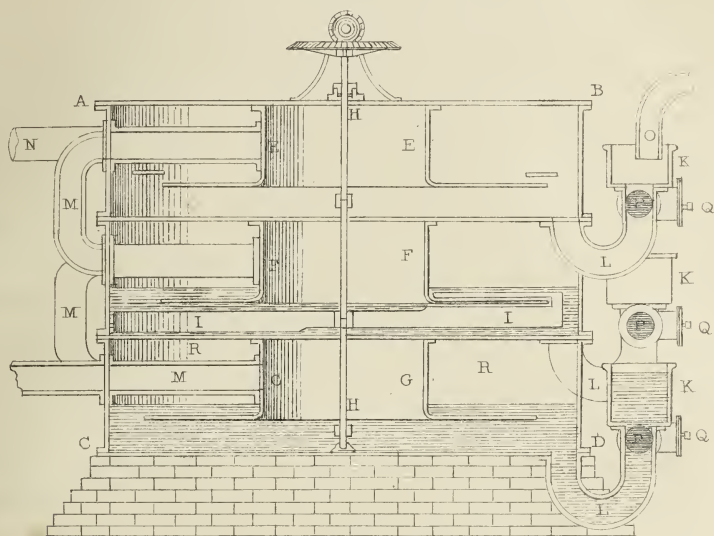
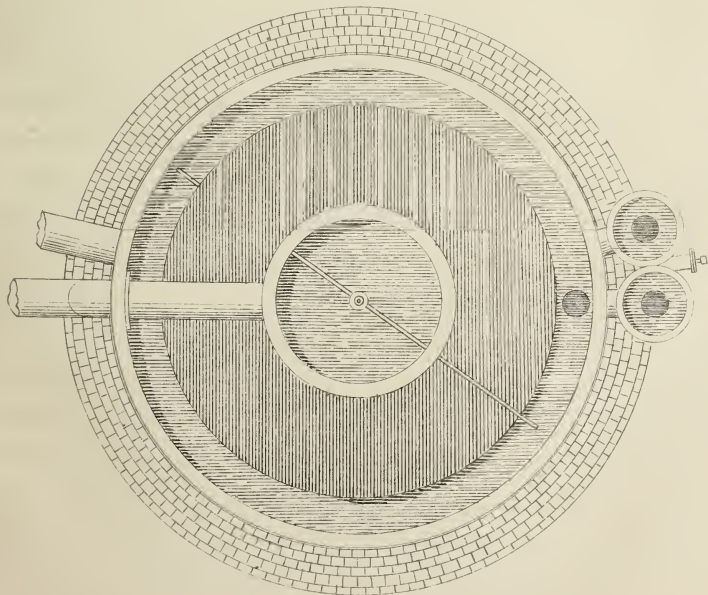


Fig. 2.



Scale  $\frac{1}{4}$  inch to a Foot

Tho.<sup>s</sup> S. Peckston.

London: Published by E. Hebert, 20<sup>th</sup> Feb<sup>y</sup> 1841

Day & Bagge, who<sup>g</sup> to the Owner



for an apparatus for purifying coal-gas by means of slaked lime, which, under certain modifications and with various improvements, is used in a great number of gas-works throughout this and other countries where gas is manufactured. As, since I first witnessed the operation of the dry lime purifier, I have put up, during the last twenty years, a great number of them, I can speak of the results obtained therefrom with that confidence which nothing save extensive experience can warrant. Prior to my being convinced, by experience, of the superiority of the dry lime system over the wet one, I was a decided advocate for the latter; but, after fixing and working dry lime purifiers at the Southampton, Portsea, and Newport (Isle of Wight) gas-works, I never have been in the habit of fixing or recommending wet lime purifiers wherever I have been employed. In speaking of the dry lime purifier, it is not, however, to be supposed that the lime is introduced into the purifier in a perfectly dry state; such is not the case. I now propose to give a description of the dry lime purifiers, and to offer a few remarks as to the mode of their operation, which I trust will be intelligible to the reader.

The purifiers on Mr. Phillips's plan are generally square (constructed of cast-iron plates); and, where there are about 500 lights to be supplied, they are about five feet square and from two to three feet deep. It requires two of them for every establish-

ment, in order that when the lime in one vessel becomes so impure as to be no longer able to deprive the refrigerated gas, as it passes through it, of its impurities, such as sulphuretted hydrogen, &c., the communication of the gas thereto may be shut off, by means of valves attached to the apparatus, and a communication opened to the one containing clean lime. Thus there is continually only one in action at one time, and whilst that is so, the impure lime is removed from the other, and a fresh charge of clean lime introduced, to be ready for use when it becomes needful for another change of purifier to take place. These vessels are secured at the bottom by an hydraulic joint, and round the top of each is a trough, of about six inches in breadth and ten inches in depth, nearly filled with water, into which the cover or lid dips, so as to prevent an escape of gas from the top. Each vessel is fitted with shelves of plate-iron, perforated with holes of about three-eighths of an inch in diameter, and distant from centre to centre three-quarters of an inch. These shelves, when fixed in their places, rest upon slight ribs cast inside upon the plates which form the sides of the purifier, in such a way as to divide the purifying vessel into three or four longitudinal compartments. At the bottom of each purifier (near the middle) is fixed the pipe which brings the impure gas into it; and a few inches above the top of this pipe is placed the first shelf,

covering the entire of the inside of the vessel ; at about eight or nine inches above it is placed the second, and the succeeding ones at equal distances one from another. In charging this purifier, the first shelf is laid in its place and covered with fresh slaked lime so far wetted as, on trial, not to adhere to or discolour the hand. In that state it is spread over the entire surface of the first shelf, to a depth of from three to four inches ; it is then wetted by a watering-can, which holds about a gallon for a purifier of the size named, the contents of which are emptied uniformly over the surface of the lime. The second, third, &c., shelves are treated in precisely the same manner ; and when they are all placed in their situations, the lid, which covers the entire of the top, is lowered into its place, dipping into the hydraulic trough already alluded to ; on this being done, the purifier is ready for action. On one side of each purifier, and above the top shelf, is the exit pipe for conveying the purified gas to the gas-holder. It has been already noticed, that the impure gas enters into the purifiers alternately, as they happen to be in action, below the bottom shelf ; and as that shelf and those above it are covered to a certain thickness with the damped lime, the gas is compelled to percolate through the lime upon each tier of shelves before it can pass away from the purifier ; and thus, according to the laws of chemical affinity, the sulphuretted hydrogen

and carbonic acid gases, &c., are arrested, and the purified gas only is allowed to find its way to the gas-holder.

In using purifiers of this description, it is found that they perform the operation of purifying better than wet lime purifiers, without being attended by several weighty objections incidental to the latter. When the lime in the dry lime purifier is saturated with sulphuretted hydrogen and carbonic acid gas, it is removed from the purifier into a proper receptacle, through which there is a current of air, which, passing over the saturated lime, carries off its volatile impurities (which are very offensive) through the main flue of the retorts into the chimney, where they are entirely destroyed. The impure lime extracted after this operation, being strongly impregnated with substances favourable to vegetation when judiciously applied, becomes a very useful manure.

The dry lime purifiers which we have described will answer very well in small works; but in large establishments, much space would be occupied by such purifiers when of sufficient power to effect the purification of the gas generated, for in works of magnitude ranges of purifiers of considerable extent would be required, in order that one range might be employed whilst the other was undergoing cleansing and recharging, in precisely the same manner as was the case when but two purifiers were used. To obviate this difficulty, a dry lime purifier was invented

by Mr. John Malam, of Hull, for which he obtained a patent in 1823.

*Plate XIV.*, *figure 1*, represents an elevation of two of the purifiers and the valve in all the leading parts similar to those for which the patent just alluded to was obtained. *Figure 2* is a plan of the same. These two figures are drawn from a scale of a quarter of an inch to a foot. *Figure 3* is a vertical section of one of the purifiers showing the lid, trough, and shelves upon which the lime is to be placed. *Figure 4* represents the bottom of the lifting valve, supposing it to be turned upside down, and *figure 5* is a section of the said lifting part of the valve. Figures 3, 4, and 5, are drawn from a scale of half an inch to a foot. In figures 1 and 2 the corresponding parts are marked with similar letters of reference. In figure 1, A and B represent two of the purifying vessels (of which it will be seen by referring to figure 2 there are four, and which on that figure are marked A B C D), each with its lid or cover marked *g* and *h* in its place, as if the purifying vessels were in action. These are supported upon piers of brickwork as at *o o o o*. E is the outer case of the centre valve, by the action of which the purifiers A, B, C, or D can be thrown out of action at pleasure. Through the bottom of this valve the pipes marked 1, 2, 3, 4, 5, 6, 7, and 8, the gas entrance pipe at the centre *i* and the exit pipe *j* rise to the height of about twelve inches, and

when the valve is prepared for action it is filled with water to the depth of about ten inches, so that the pipes just named are all surrounded to that depth with water. The interior or lifting part made of cast-iron, represented in figure 2 and in figures 4 and 5 on a larger scale, (which will be more fully described hereafter,) is then placed over the pipes with its open part downwards, which dips in the water to the height at which the water stands in the valve, and so that the part marked 1 in figure 4 shall be over the pipe marked I figure 2; when it is so, it is evident that the gas which enters the valve at its centre by the pipe *i* cannot escape therefrom but by passing down the pipe 1, no other pipe in the valve being connected with that partition, the water sealing the partition plates of the lifting valve: and on examining figure 2, it must likewise be evident that (in the situation the lifting part of the valve is there shown without its top to expose the orifices of the pipes) the gas passing down pipe 1 will proceed by the pipe opposite thereto into the purifier marked C, into which purifier it enters below the bottom tier of shelves as shown in section in figure 3. After having percolated through the lime spread over the shelves in the way described at page 245, it finds its way to the top of the purifier, from whence it descends towards the bottom over the partition plate *ef*, which goes quite across the purifier and close to its bottom, and rises about six inches above

the top tier of plates upon which the lime is laid. This plate is cast with a flanch at each side and at the bottom, so that it may be jointed to the sides and bottom and made gas-tight. On reaching the bottom of this partition, the gas makes its exit from the purifier C by the bend-pipe shown at the side opposite to that at which it made its entrance; and through the pipe thereunto connected it proceeds again to the valve rising through the pipe marked 2 into that partition of the lifting valve which encloses the pipes marked 2 and 3. From that partition it cannot escape except by passing down the pipe 3; it does so, and by the pipe in a line therewith it finds its way under the bottom shelf of the purifier A, where, after having percolated through the lime as already mentioned when speaking of the purifier C, it passes over the partition *ef*, and thence, by means of the pipe *k*, again into the valve into which it rises by the pipe marked 4; here again it can find no way of escape except by descending through the pipe marked 5, the pipes 4 and 5 being enclosed within one partition of the lifting part of the valve. The pipe marked 5 conveys the gas by the pipe *m* into the purifier marked B, in which it percolates through the lime till it rises to the top of that purifier; it then descends over the partition *ef*, and thence by the bends and pipes shown, as proceeding from the end opposite to that at which it entered that purifier, it finds its way

into the centre valve through the pipe marked 6. On referring to the plan of the centre valve, it will be seen that the lifting part of that valve shuts off all communication with pipe 6 from all the pipes the valve contains except the one marked *j*, and that that pipe is connected with the one which leads toward the gas-holder—the gas having, ere it reaches the pipe *j*, been thoroughly deprived of all its impurities from having passed through three purifying vessels, each containing seven tiers of lime of from three to four inches in thickness, through which number of purifiers it is always obliged to pass on its way from the condenser to the gas-holder. In figure 2, the purifier marked D is represented as entirely shut off from the centre valve, the partition of the lifting part of that valve which falls over the entrance pipe thereto and exit pipe therefrom, pipes 7 and 8 shutting off all gas communication of any other part of the centre valve with the purifier D. Such will be the case with respect to the purifiers C, A, or B, according to the position in which the lifting valve may be placed; for if the valve be lifted and turned one quarter round, that part which now covers pipes 7 and 8 will, when again lowered, shut off the entrance and exit pipes of the purifier C, and throw it out of and bring the purifier D into action when the part of the lifting valve which is represented over the pipe marked 1 would fall over the pipe marked 3, which would convey the impure gas

into the purifier A, thence by a similar route to the purifier B, and subsequently to C, from whence, after it had returned to the valve, it would find its way to the gas-holder by the pipe *j*. It is evident, therefore, that by raising the lifting part of the valve so that its lowermost edge may be above the top of the pipes in the valve, (till it is in such a position it cannot be turned round,) turning it one quarter round and then lowering it into the water, the gas can be shut off in succession from the purifier D, (as shown in figure 2,) C, A, or B, as may be necessary. The interior or lifting part of the valve has an upright rod or shaft passing through its top at the centre, secured by a collar above, and a nut and washer below, as shown in figure 5; which nut ought to be screwed up very tight, and the end of the rod should be well burred up to prevent the nut slipping or the shaft turning without the lifting part turning with it. This shaft passes through a stuffing-box as shown at the top of E, figure 1, and is continued (having a square thread screw about eighteen inches long at its upper end) through the dome-shaped casting marked *f*, which is supported by four cast-iron pillars equidistant secured to the lid of the valve E. The tongue *d*, figure 1, slips over the shaft *c*, and is secured thereto by a key in the situation as shown in the figure which represents the lifting part of the valve as let down in its place: the opposite end of the tongue has a notch in it,

which works upon a narrow slip cast upon each of the four pillars already mentioned (of which two only are shown, *a* and *b*). These slips do not rise to the entire height of the pillar, but sufficiently high to indicate when the lower edge of the lifting part of the valve is clear of the top of the upright pipes therein. We will suppose now that the pillars are so placed that they are respectively opposite to the purifiers D, C, A, and B, and that if the tongue be lowered upon the slip attached to the pillar opposite D, the purifier D will be thrown out of action if opposite C; the purifier C, opposite A; the purifier A, and opposite B, the purifier B will be thrown out of use. When therefore it is necessary to throw any one of the purifiers out of action, the lifting valve is raised by means of the handle *e*, which works upon the screwed part of the shaft *c*, till the tongue rises above the slip attached to the pillar towards which it then points, the tongue is then laid hold of and turned to the left till the notch at the end of it is directly over the slip attached to the next pillar, when by the handle and screw it is lowered till the tongue rests upon the top of the stuffing-box already described, when the operation of shifting the valve is finished. The whole operation does not occupy more than a few minutes.

*Figure 2* is a plan of the purifiers A, B, C, and D; their centre valve shown without its top, and the lifting part of the valve also without its top, 1,

2, 3, 4, 5, 6, 7, and 8, situation of pipes for conveying the gas from one part of the valve, and from one purifier to another, and subsequently by means of the pipe *j*, continued in plan at *j*, outside the valve, towards the gas-holder. The impure gas enters this valve through the pipe marked *i*, outside the valve at its centre. *a, b, c, d*, plans of outside of troughs; and *e f*, the partition plates over which the gas passes when leaving each purifier, as has been already described.

*Figure 3* is a vertical section of the purifier C, in a direction parallel to *b d*, *figure 2*, which is given for showing how the gratings or perforated shelves are fixed. It will be seen that there are slips *k k* cast on the side plates upon which one end of the shelves rest, and also that there are steps cast inside the end plates, as at *h*, for receiving the T-shaped cross-bars, upon which the other ends of the shelves or gratings are supported. In this figure the gratings are represented as in two lengths for each tier, and are marked *e* and *f*. They ought not, however, for convenience of handling, to be more than two feet in length by one foot six inches in width. I have found in practice, cast-iron gratings (about three-eighths of an inch in thickness, with a rim round each about one inch or one inch and a quarter broad, cast solid, the other part being cast with open slits about a quarter of an inch in breadth, and distant from each other a quarter of an inch, so as to

give them the appearance of a grating) very preferable to shelves made of boiler-plate, and perforated as has been already described, being much more durable, and more easily, and at less expense, replaced when worn out. *a, b, c, d*, section of the trough which goes round the purifier, to be kept filled with water to a depth of five or six inches, into which trough the lid marked *g* or *h* drops, so that, when in its place, as shown in this figure, the escape of gas is prevented by an hydraulic joint. In the centre of the lid must be fixed an eye-bolt, through which a hook can be fixed attached to a swinging crane with a screw or pulleys (not shown in the figure) thereto for raising the lid when it is required to cleanse and recharge the purifier, during which operation the lid can be swung on one side so as to be out of the way, and swung back, and again lowered into its place when the operation is completed. The pipe marked with an arrow shows in what a situation the gas is brought into the purifier, namely, below the bottom lime shelf.

*Figure 4* represents the bottom of the lifting part of the valve, supposing it to be laid upon its top, consequently the reverse way to that shown in figure 2.

*Figure 5* is a section of the lifting part of the valve, with a part of the upright shaft, the collar and nut for securing it.

Having sufficiently explained the construction of

this purifier, and the manner in which, by the action of the centre valve, the purifier A, B, C, or D, can be thrown out of action at pleasure, we come now to speak of the mode of working it; and in doing so, we will suppose that the machine is perfectly new, and is about to be used for the first time. We will also suppose that the lifting part of the centre is placed in the position shown in figure 2, so that there is no communication between the centre valve and the purifier D, but between the centre valve and the inlet and outlet pipes, and the purifiers C, A, and B. The lids being removed from each of these purifiers, the first row or tier of gratings are placed on the lowermost ledges and the cross-bar, as shown in figure 3, and covered with lime, in precisely the same way as has been already described when speaking of this same purifier in its more primitive form, taking care that each tier of lime be well wetted before the next set of gratings above it are fixed in their places, and thus proceeding with each row of gratings and layers of lime upon them till the proper number are fixed in the purifier C. Proceed in exactly the same manner with the gratings and layers of lime in the purifiers marked A and B, till the entire of the gratings they are intended respectively to contain are in their places, and the layers of lime well wetted are upon them. This being done, let the lids be lowered over the respective purifiers. To prevent the lids forcing the water out of the troughs of their respective purifiers,

a hole three quarters of an inch in diameter is tapped and drilled in each, and these are each fitted with a screwed plug, which should be removed prior to lowering the lid, to allow the compressed air caused by its immersion in the water to escape. These plugs should also be removed when the lids are to be lifted, to prevent the water being drawn out of the trough. It is well to have also a smaller hole tapped in each lid, say of half an inch diameter, fitted with a short piece of iron tube, a cock, and a jet burner for testing the gas, as will be hereafter described. These cocks should be kept always shut, except when it may be necessary to test the purity of the gas. We will now suppose the lids are all lowered into their places, and that the gas then being made has found its way through the washer and condenser to the pipe *i*, by which it enters at the centre of the lifting part of the valve, as has been already described, and thence into the purifier C, which purifier it enters in its most crude state, and passes through the seven layers of lime which are placed therein, and by which it is deprived of a large portion of the impurities which it contained when it first entered into that vessel. The gas so far purified, returns to the centre valve, and thence under the lowermost layer of lime in the purifier A : in that it passes through the seven layers of lime as before in the vessel C, which take up an additional quantity of the impure matter ; it then returns again to the centre valve doubly purified, and

thence again under the lowermost layer of lime in the purifier B, passes through an equal number of layers of lime in that purifier, as it had done in passing through the purifiers C and A respectively, whence it proceeds, trebly and practically thoroughly purified, to the centre valve, which it enters by the pipe marked 6, and thence by the pipe *j* it flows to the gas-holder. From what has been said, it will be understood that the gas enters (when the position of the lifting valve is as shown in figure 2) first into the purifier C, next into A, and lastly into the purifier B, when on its way from the condenser to the gas-holder. It follows then in consequence, that as the purifier C receives the gas in its most impure state, the lime therein will be first saturated with impure matter : when such is the result in the purifier C, the lime in the purifier A will be but slightly discoloured, and that in the purifier B hardly changed from the state in which it was when the operation was commenced. Whilst the purifiers C, A, and B are in action, the purifier D should be charged with lime in the same way as the others were, and its lid lowered preparatory to its being brought into use. To know when it is necessary to throw the purifier C out of action, the gas must be tested at the jet burner attached to the lid of the purifier B (the last of the acting series as the lifting part of the centre valve is placed), where the gas is in its most pure state. If the test applied indicate the

slightest trace of impure matter, it is time to throw the purifier C out of action, which is effected in the way already described ; then A becomes the first of the series, B the second, and D the third or last. When such is the case, let the lid of the purifier C be removed, and the impure lime withdrawn thence, then let it be well washed and cleansed inside ; let the gratings also be well washed preparatory to the said purifier being again charged, in order that no impure matter may remain upon them, or within that vessel when the fresh charge is introduced. By being careful as to these matters, the purity of the gas will be greatly ensured ; for it is very essential towards ensuring the purity of the gas, always to keep quite clean the last purifier of the series in action, which the gas has to pass through. Let the purifier C be again charged with lime, and when the gas tested at purifier D (then the last of the acting series) indicates impurity, throw the purifier A out of action, by doing which the purifier C will be brought into use ; then proceed with the purifier A as has been done with the purifier C, and so on in succession continually as the case may require ; for, having begun with C as the first of the series, A became next so, and now B, by throwing A out of action, has become so, and C is the last. The next change will make D the first of the series, and A the last, and the charge which throws D out of action will leave the lifting part of the centre valve in

the same situation as when the purifier was first brought into action : for either the purifiers (C, A, B), (A, B, D), (B, D, C), or (D, C, A), in the order in which the letters stand, must, from the construction of the centre valve, be in action at one time, as has been very fully explained, and as a reference to the plate will show.

In order that the public may, on all occasions, be supplied with pure gas, we have been very particular in describing such a purifier as cannot fail to furnish it, if the directions for its proper management be attended to. This description of purifier possesses many advantages over the wet lime apparatus : first, from its construction it admits of each purifier of the series, as it is thrown out of use, being thoroughly cleansed ; so that when the purifier is again brought into action, its interior is free from all impurities : such can never be the case with the wet lime purifiers, for, when they are once brought into action, there is no means of cleansing the inside of them without entirely stopping the operation of making gas, and much labour and expense in removing their lids or man-holes, left for the purpose of getting into them ; whence it follows that they generally are worked for a very long period without any attention being paid to the extraction therefrom of the impure matter which gradually accumulates therein. The consequence of these several facts is, that even when three wet lime purifiers are

used, one after another, the interior of the last of the series becomes so foul, as to deprive the fresh lime introduced of much of its purifying power; that is, the impure matter saturates it to a certain extent, and thus so far is injurious: but, where a single wet lime purifier only is used, the evil is much greater; so that to expect pure gas from works where only one wet lime purifier is used, is to expect what may be set down as impossible, let the purifier be charged with fresh lime ever so often. In the second place, the dry lime purifier does not produce so great a bulk of offensive matter as the wet one. In the first, the lime, when it is removed, does not exceed its bulk when first slaked. In the latter, being mixed with water till it is of the consistence of cream, the quantity of matter drawn off from the purifier is amazingly increased, and requires, in extensive works, very large tanks or cess-pools for its reception, in which the saturated lime subsides, and becomes of the consistence of mud; whilst the water, impregnated also with much impure and offensive matter, is pumped off, and evaporated in pans under the fire-places for heating the retorts, engendering by its noisome smell a most abominable nuisance, which extends to a considerable distance from the manufactory in all directions. And if by any chance the cess-pools should overflow (which has often happened), and the impure water find its way into a drain or sewer,

it would soon contaminate such sewer through all its ramifications, and show its deleterious effects in every house it passed by, from the vapours arising from it finding their way into the house through sinks, crevices, or otherwise, discolouring all the white painting, tarnishing all silver and plated goods, &c., as well as annoying the inmates by its very disagreeable odour. The removal of the subsided lime is also another cause of nuisance; for, in carrying it away from time to time from the works, in every thoroughfare through which it may pass, the noxious properties which it contains give out their offensive odour abundantly from the jolting of the vehicle employed. As the dry lime purifier, on the contrary, produces no liquid to be disposed of, and when the impure lime requires to be removed, it is in a perfectly dry state; consequently the removal can be effected without any nuisance being created. With respect to the efficiency, as a means of purifying coal-gas, of the wet lime purifier, compared with that of the dry lime purifier, the latter far exceeds the former, as must be quite evident when what has been said upon the matter is duly considered.

We consider what we have said quite enough for all practical purposes, on the subject of purifying coal-gas; but before we conclude this chapter, we may remark that M. Blondeau de Carolles has recently objected to the use of lime as a sufficient

medium of purification ; stating that the lime used in the ordinary purification decomposes the hydro-sulphate of ammonia, seizes the sulphuretted hydrogen, and, liberating the ammonia which mixes with the lighting gas, communicates thereto a disagreeable odour, and diminishes its illuminating power : he therefore recommends that the gas, after passing the ordinary purifier, should be made to pass through layers of coke covered with layers of chloride of calcium, both of which substances have the property of absorbing ammonia. (See "The Chemist" for February, 1841, page 50.)

For depriving gas of its ammonia, a patent was obtained in January, 1841, by Mr. Alexander Angus Croll, superintendent of the Gas Light and Coke Company's Works, Brick-lane, Middlesex. He proposes to pass the gas as it comes from the retorts through a vessel similar to the single wet lime purifier filled with a solution of chloride of manganese in water, in the proportion of one hundred-weight of the former to forty gallons of the latter. The gas is made to pass through this solution by pressure from the retorts, in the usual way, and the ammonia and a portion of its sulphuretted hydrogen are abstracted ; the remaining portion of the sulphuretted hydrogen is extracted by the usual methods. When the solution is saturated with ammonia, which can be known by the application of proper tests, it is to be drawn off and the vessel recharged

with a fresh solution. He also states that sulphuric or muriatic acid may be used in a washer for the same purpose, the former in the proportion of  $2\frac{1}{2}$  pounds of sulphuric acid (specific gravity 1.845) to 100 gallons, through which the gas is to pass, till the mixture indicates a specific gravity of 1.170; and, on being tested, is found to be saturated with ammonia. When muriatic acid is used, it should be of specific gravity 1.165, and in the same proportion as mentioned for sulphuric acid, which is to be drawn off when it attains a specific gravity of 1.170. The patentee prefers using sulphuric acid, but states that sulphate of manganese and muriate of iron may also be used for these purposes. In his "Specification," Mr. Croll claims the method of reproducing the ammoniacal salts, &c., which he there describes, but which it is not necessary to dwell upon here, for the invention being patented, the patentee will of course answer any inquiry that may be made relative to the mode of operation.

We shall not say more on the subject of purification here, than that in practice, when the wet lime purifier is used, about an imperial bushel of unslaked lime is considered sufficient for purifying from 10,000 to 12,000 cubic feet of gas, when obtained from almost any of the Newcastle coals, in which proportion the purifier ought to be charged for larger or for smaller quantities; however, as the qualities of coal vary considerably, perhaps no spe-

cific quantity can be put down as a general rule. The operator must frequently test the gas immediately after it has passed through the purifier; and when he finds his test discoloured, he will of course change his lime. Indeed the testing the gas at stated intervals, and acting with the purifiers accordingly, is the only way of ensuring pure gas. In the dry lime purifier, the same quantity of lime in proportion to the quantity of gas to be purified, as has been mentioned for the wet lime purifier, will be sufficient. Most kinds of quick lime double their bulk on being slaked.

## CHAPTER XI.

On the Gas-holder (Gasometer) and its Construction, with Descriptions of such as are generally used.

THE gas-holder (or, as it was formerly, and is still sometimes, though improperly, called the *gasometer*) is that vessel in which the purified gas is stored up for use. It has been made of various sizes and shapes. It is now generally cylindrical, though some years ago many were constructed either square or oblong, at the caprice of the manufacturer. When speaking of the gas-holder, we are to be understood as referring to two distinct parts; that is to say, a capacious inner vessel in large works, almost universally made of sheet-iron, which is closed at the top and open at the bottom, and a tank of cast-iron, brick-work, or masonry (formerly large wooden vats were occasionally used), of about a foot or eighteen inches greater diameter than the gas-holder itself, for containing water into which the gas-holder sinks as the gas is drawn away from it by supplying the company's customers, and which rises therein as it receives the purified gas from the manufactory: it is however so contrived, that it cannot rise high enough to raise its bottom edge nearer than two inches to the surface of the water

which the tank contains—a precaution necessary to be taken, in order to prevent the gas from blowing under the lower edge of the gas-holder.

Before entering upon various topics connected with the construction of gas-holders, and tanks for them to work in, it may be desirable to describe one of the most simple construction. Plate XV., *figure 1*, is a vertical section of a gas-holder (working in a cast-iron tank), of its bridge, chain, and counterpoise, or balance-weights; A B C D is a section of the gas-holder; E F G H a section of the tank; I I, cast-iron flanch pipes jointed together in the usual way, so as to form columns for supporting the frame K K. Upon this frame are placed carriages for bearing the grooved wheels L L, over which runs the chain suspending the gas-holder, and sustaining the balance-weight M. N is the pipe which conveys the gas into the gas-holder after it has been purified; O another pipe similar to the former, by which the gas is conveyed into the main pipe connected with the streets, where the gas is to be used. It need hardly be remarked, the upper end of these pipes, N and O (the inlet and outlet pipes), must rise two or three inches above the surface of the water in the tank, to prevent a possibility of water getting into them. Upon the horizontal part of the pipes N and O are placed valves for shutting off the respective communications when the vessel is full, or when it may be desired not to work it. The figure

represents the gas-holder as if it were about half full of gas. Plate XV., *figure 2*, represents the plan of the gas-holder just described. It will be seen, by referring to the figure just described, that the gas-holder is suspended by a chain over two grooved wheels, fixed upon a cast-iron frame placed over it; one end of which chain is made fast to an eye-bolt at the centre of the top of the gas-holder, and to the other is attached a rod or frame for supporting certain weights which counterpoise a certain part of the gas-holder. It is to be observed that, by putting more weights upon the counterpoise support, or frame, the gas-holder works at less pressure, and consequently does not force the gas into the street mains with such velocity as it does when the weight is there diminished: for, if the balance-weight and weight of the gas-holder be very nearly equal, then there will be but little or any impetus arising from the weight of the gas-holder to discharge the gas; it would, in consequence, escape with such languor at the orifices of the burners as to afford but a very feeble light. To obtain a good light, the gas-holder should never be worked at less than from fourteen-tenths of an inch to two inches pressure; or, in other words, the surface of the water inside the gas-holder should be from fourteen-tenths of an inch to two inches below the surface of the water contained between the

outside of the gas-holder, and the tank or vat in which it may be suspended.

If we suppose the tank to be filled with water, and the gas-holder partly filled with gas, we can so adjust the counterpoise or balance-weight as to produce an equilibrium between it and the gas-holder. When the counterpoise is so adjusted, the water will stand at the same level inside the gas-holder, as what it stands at between the outer surface thereof and the inside of the tank. But, by diminishing the counterpoise, the gas-holder will, by its gravity, have a tendency to descend; and the greater that tendency may be, so much more will the water descend within it. Under these circumstances, the included gas will be compressed beyond the pressure of the atmosphere, in exact proportion to the weight of a column of water whose height is equal to the difference between the surface of the water inside the gas-holder, and the surrounding surface of the water between the outside of the gas-holder and the tank in which it works.

For ascertaining the pressure at which the gas-holder works, a small pressure gauge may be attached to the top of it, or connected to the outlet pipe therefrom, which may be secured from accidental injury by a wrought-iron case. When, from the gas having been allowed to enter into the gas-holder, it has risen but a few feet out of the water,

if the graduated scale on the pressure gauge be inspected, it can be seen at what pressure the gas-holder is then working ; and by increasing or diminishing the counterpoise or balance-weight, the gas-holder can be regulated or adjusted to the desired pressure. One of the uses of the gas-holder is to regulate the emission of the gas towards the burners where it is to be used, which could not be effected without some such contrivance as the gas-holder ; the gas being evolved from the retorts in very unequal proportions during the different periods of the distillatory process, as has been already noticed in the chapter relative to carbonization.

On considering the matter a little closely, we cannot fail to perceive that, as the gas-holder fills with gas, the weight thereof will be continually increasing ; for we know that “ a body immersed in a fluid will sink to the bottom if it be heavier than a bulk of fluid equal to it ; and if it be suspended in it, it will lose as much of what it weighed in air as its bulk of the fluid weighs.” The case is precisely the same with the gas-holder : for when the gas first begins to enter into it, its top is level with the water, it will therefore be counterpoised in such a situation by a weight that wants as much of the absolute weight of the gas-holder as the quantity of water weighs which is thereby displaced. As the gas is allowed to enter the gas-holder, the latter rises out of the water, and of course, as it does so,

its weight increases ; therefore, if the balance-weight be barely sufficient to support the gas-holder, so that it may work at a certain pressure when it first begins to rise out of the water, it follows that, as it rises, the pressure increases by the increasing weight of the gas-holder. If then the gas-holder be worked without any contrivance for regulating the pressure, the quantity of gas it may contain (from the variability of the pressure) cannot be accurately ascertained ; nor can the gas therefrom, when permitted to flow to the burners where it is to be used, be uniformly supplied, so that the flame from the burner shall continue of a constant height during the time it may remain burning ; for when the gas-holder is nearly full of gas, it will work at a much greater pressure than when it is nearly empty. The flame, therefore, will be much longer in the first case than in the last, without any possibility, for want of an equalizer of pressure, of its being at a uniform height. It is evident, from what has been just said, that unless there be some contrivance in works of magnitude for keeping the gas-holders at a uniform pressure at all heights, very serious inconveniences must inevitably ensue.

When the manufacture of coal-gas was in its infancy, a spiral pulley (on the principle of the fusee of a watch) was used for the chain to work over, for the purpose of counteracting the evils attendant upon the want of uniformity in the pressure of the

gas-holder. It answered the intended purpose ; but it was clumsy, inconvenient, and expensive. A deviation therefrom was made for gas-holders working on the ordinary principle, built upon the theorem we have already mentioned ; that is to say, “ a body immersed in a fluid loses as much weight as an equal bulk of the fluid weighs.” It will doubtless appear evident to our readers, that the only mode for effecting the purpose (when gas-holders are fitted up with a constant equilibrium apparatus) will be by increasing the weight which is suspended as a balance over the friction-wheels, in proportion to the weight of water displaced by the descent of the gas-holder : and therefore, as the balance-weight itself remains the same, it must be done by a compensation of weight in the chain supporting it. To ascertain the weight per foot of this chain, we are first to consider what quantity of water will be displaced by the sides of the gas-holder being immersed therein to the depth of one foot, and thence the weight of that water, which can be done by multiplying the circumference of the gas-holder in inches, by 12 inches, the depth spoken of, and that again by the thickness of the metal of which the gas-holder is composed, making an allowance for overlap of plates, rivets, and internal stays of 20 per cent., which will give the bulk of water displaced in most cases. Thus the circumference of a gas-holder, 60 feet diameter, being 188·4

feet or 2260 inches  $\times 12 = 27,120 \times \frac{1}{16}$ th of an inch (the thickness of the iron of which the sides are composed) = 1695 cubic inches; to which add 20 per cent. for overlap of plates, &c., (339) we have 2034 cubic inches of water displaced by the immersing a gas-holder 60 feet in diameter one foot deep in water. The water displaced weighs 1177 oz., or 73 lbs. 9 oz.; 2034 cubic inches of plate-iron, specific gravity 7.788, weigh about 573 lbs., of which it loses 73 lbs. 9 oz. by immersion; consequently the chain of equilibration must have each foot of it of such weight as to make up for the difference on a foot rise, or the whole length to make up the difference of the whole rise. For example: we will suppose the weight M, figure 1, Plate XV., is resting upon the ground near the foot of the column marked I, in which situation the gas-holder, A B C D, would be acting with the greatest pressure (supposing there were no weight or chain); we will further suppose that the entire height the gas-holder rises is 18 feet: it follows therefore that the weight of each foot of chain from M towards L should be one-half of the weight of the water displaced by the immersion of the gas-holder; because, as the gas-holder descends one foot, the chain from the centre of its top descends also with it, consequently adding to the weight of the gas-holder the weight of one foot of chain; but as that descent raises the counterbalance M, and

shortens the chain from M towards L one foot, it takes away the weight of one foot of that part of the chain; consequently what is lost in weight there, being added to what is gained in weight by the chain which passes over the pulley, which is placed over the centre of the gas-holder, gives the entire weight of the water displaced by immersion of the gas-holder; and thus the pressure is kept uniformly the same at every height of the gas-holder. Therefore, if there be given the weight of the sides of the gas-holder, which is immersed into the water one foot, and the specific gravity of the material of which it is composed, the specific gravity of water being 1.000, we can easily ascertain what weight one foot in length of the equilibration chain ought to be by the following—

**RULE.** As the specific gravity of the material of which the gas-holder is composed

Is to the specific gravity of water,

So is the weight of that part of the gas-holder which becomes immersed in water

To the weight of a bulk of water equal to that which is displaced by the immersion of the gas-holder: consequently, from what has been already premised, to double the weight of that part of the chain supporting the counterpoise which is equal in length to such immersion, whether it be one foot or any greater number of feet.

*Example 1st.* Given the specific gravity of sheet-

iron 7·788, and the weight of one foot in height of the sides of a gas-holder constructed of such material 573 pounds, to find the weight of water displaced by the gas-holder, and consequently to find the weight of one foot in length of the equilibration chain,—

Specific Gravity of Sheet-Iron.	Specific Gravity of Water.	Weight in lbs. of one foot in height of sides of Gas-holder.	Weight of Water in lbs. displaced by one foot descent of Gas-holder.
Say, as 7·788	: 1·000	: : 573	: 73·57

nearly one-half of which is the weight per foot of the equilibration chain, namely, 36·785 pounds, or 36 pounds 12 ounces.

*Example 2nd.* Given the specific gravity of sheet-copper 8·878, and the weight of one foot in height of the sides of a gas-holder constructed of such material 653 pounds, to find the weight of water displaced by the gas-holder, and consequently to find the weight of one foot in length of the chain of equilibration,—

Specific Gravity of Copper.	Specific Gravity of Water.	Weight in lbs. of one foot in height of the sides of Gas-holder.	Weight of Water in lbs. displaced by one foot descent of the Gas-holder.
Say, as 8·878	: 1·000	: : 653	: 73·55 nearly,

one-half of which is the weight per foot of the chain of equilibration, namely, 36·775 pounds, or 36 pounds 12 ounces, as in the first example: hence it is evident that whatever may be the specific gravity of the material of which the gas-holder is constructed, the weight per foot of the equilibration chain will always be equal to the weight of one-

half of the bulk of water displaced by the gas-holder being immersed one foot.

This matter, it is hoped, has been made sufficiently clear to the reader, so that he can with ease adjust the weight of the equilibration chain. We shall next introduce something relative to the pressure of fluids, which is a subject of importance to those who may have occasion to construct tanks for the gas-holders to work in, or other vessels of magnitude sometimes required in a gas-manufactory. We do so from being aware how very frequently *weight* and *pressure* are confounded by those who have not made themselves thoroughly acquainted with the laws of Hydrostatics.

**PROPOSITION I.** *If any part of a fluid be raised higher than the rest by any force, and then left to itself, the higher parts will descend to the lower places, and the fluid will not rest till its surface be quite even and level ;*

For, the parts of a fluid being easily movable every way, the higher parts will descend by their superior gravity, and raise the lower parts till the whole come to rest in a level or horizontal plane.

*Corol. 1.* Hence water, which communicates with other water by means of a close canal or pipe, will stand at the same height in both places. In the same way, should a glass syphon be held with the bend part downwards and water be poured into one

of the legs, it will pass through the bend and stand at the same height in each of its legs.

*Corol. 2.* For the same reason, if a fluid gravitate towards a centre ; or, in other words, if it be received into an inverted cone, it will dispose itself into a spherical figure, the centre of which is the centre of force. Like as the sea in respect of the earth.

PROPOSITION II. *When a fluid is at rest in a vessel, the base of which is parallel to the horizon, equal parts of the base are equally pressed by the fluid ;*

For upon every part of the base there is an equal column of the fluid supported by it. And as all the columns are of equal height, by the last proposition, they are of equal weight, and therefore they press the base equally ; that is, equal parts of the base sustain an equal pressure.

*Corol. 1.* All parts of the fluid press equally at the same depth ; for if a plane, parallel to the horizon, be conceived to be drawn at that depth, then the pressure being the same in any part of that plane, by the proposition, therefore the parts of the fluid, instead of the plane, sustain the same pressure at the same depth.

*Corol. 2.* The pressure of the fluid at any depth is as the depth of the fluid ;

For the pressure is as the weight, and the weight is as the height of the fluid.

PROPOSITION III. *When a fluid is pressed by*

*its own weight, or by any other force ; at any point it presses equally, in all directions whatever.*

This arises from the nature of fluidity, by which it yields to any force in any direction. If it cannot recede from any force applied, it will press against other parts of the fluid in the direction of that force. And the pressure in all directions will be the same. For, if it were less in any part, the fluid would move that way, till the pressure be equal every way.

*Corol. 1.* In a vessel containing a fluid the pressure is the same against the bottom as against the sides ; or even upwards at the same depth.

*Corol. 2.* Hence, and from the last proposition, if  $ABCD$  (Plate I., fig. 5) be a vessel of water, and there be taken, in the base produced,  $DE$  to represent the pressure at the bottom ; joining  $AE$ , and drawing any parallels to the base, as  $FG$ ,  $HI$  ; then shall  $FG$  represent the pressure at the depth  $AG$ , and  $HI$  the pressure at the depth  $AI$ , and so on ; because the parallels  $FG$ ,  $HI$ ,  $ED$ , by similar triangles, are as the depths  $AG$ ,  $AI$ ,  $AD$  ; which are as the pressures by the proposition.

And hence the sum of all the  $FG$ ,  $HI$ , &c., or area of the triangle  $ADE$ , is as the pressure against all the points  $G$ ,  $I$ , &c., that is, against the line  $AD$ . But, as every point in the line  $CD$  is pressed with a force as  $DE$ , and that thence the pressure on the whole line  $CD$  is as the rectangle  $ED$ ,  $DC$ , whilst that against the side is as the triangle  $ADE$ , or

$\frac{1}{2}AD, DE$ ; therefore the pressure on the horizontal line  $DC$  is to the pressure against the vertical line  $DA$ , as  $DC$  to  $\frac{1}{2}DA$ . And hence, if the vessel be an upright rectangular one, the pressure on the bottom, or whole weight of the fluid, is to the pressure against one side as the base is to half that side: and, therefore, the weight of the fluid is to the pressure against all the four upright sides as the base is to half the upright surface. And the same holds true also in any upright vessel. Or, in the cylinder, the weight of the fluid is to the pressure against the upright surface as the radius of the base is to double the altitude.

Moreover, when the rectangular prism becomes a cube, it appears that the weight of the fluid on the base is double the pressure against one of the upright sides, or half the pressure against the whole upright surface.

*Corol. 3.* The pressure of a fluid against any upright surface, as the gate of a sluice or canal, is equal to half the weight of a column of the fluid whose base is the surface pressed, and its altitude the same as the altitude of that surface.

For, the pressure on a horizontal base, equal to the upright surface, is equal to that column; and the pressure on the upright surface is but half that on the base, of the same area.

So that, if  $b$  be the breadth, and  $d$  the depth of such a gate or upright surface, then the pressure

against it is equal to the weight of the fluid, whose magnitude is  $\frac{1}{2} b d^2 = \frac{1}{2} A B, A D^2$ .

If the fluid be water, a cubic foot of which weighs 1,000 ounces, or  $62\frac{1}{2}$  pounds; and, if the depth  $A D$  be 12 feet, the breadth  $A B$  20 feet; then the content, or  $\frac{1}{2} A B, A D^2$ , is 1440 feet, and the pressure is 1,440,000 ounces, or 90,000 pounds, or  $40\frac{1}{3}$  tons weight nearly.

**PROPOSITION IV.** *The pressure of a fluid, on the base of the vessel in which it is contained, is as the base and perpendicular altitude, whatever be the figure of the vessel that contains it.*

If the sides of the base be upright (Plate I., fig. 6), so that it be a prism of an uniform width throughout, then the case is evident; for then the base supports the whole fluid, and the pressure is just equal to the weight of the fluid.

But if the vessel be wider at the top than bottom, then the bottom sustains, or is pressed by, only the part contained within the upright lines  $a C, b D$  (Plate I., fig. 7); because the parts  $A C a, B D b$ , are supported by the sides  $A C, B D$ ; and these parts have no other effect on the part  $a b D C$  than keeping it in its position by the lateral pressure against  $a C$  and  $b D$ , which does not alter its perpendicular pressure downwards; and thus the pressure on the bottom is less than the weight of the contained fluid.

And, if the vessel be widest at the bottom, then

the bottom is still pressed with a weight which is equal to that of the whole upright column  $ABDC$  (Plate I., fig. 8): for, as the parts of the fluid are in equilibrio, all the parts have the same pressure at the same depth; so that the parts within  $Cc$  and  $dD$  press equally as those in  $cd$ , and therefore equally the same as if the sides of the vessel had gone upright to  $A$  and  $B$ , the defect of fluid in the parts  $ACa$  and  $BDb$  being exactly compensated by the downward pressure or resistance of the sides  $aC$  and  $bD$  against the contiguous fluid. And thus the pressure on the base may be made to exceed the weight of the contained fluid, in any proportion whatever.

So that, in general, be the vessels of any figure whatever, regular or irregular, upright or sloping, or variously wide and narrow, in different parts, if the bases and perpendicular altitudes be but equal, the bases always sustain the same pressure; and as that pressure, in the regular upright vessel, is the whole column of the fluid, which is as the base and altitude, therefore the pressure in all figures is in the same ratio.

*Corol.* 1. Hence, when the heights are equal, the pressures are as the bases; and when the bases are equal, the pressure is as the heights; but when both the heights and bases are equal, the pressures are equal in all, though their contents be ever so different.

*Corol. 2.* The pressure on the base of any vessel is the same as on that of a cylinder of an equal base and height.

*Corol. 3.* If there be an inverted syphon, or bent glass tube, the legs of which are of different lengths, containing two different fluids that balance each other, or rest in equilibrio, then their heights in the two legs above the point of meeting will be reciprocally as their densities : or,

As the height of one fluid is to the height of the other,

So is the density of the latter to the density of the former :

So, if the longer leg of the syphon contain water to the height of fourteen inches, it will be kept in equilibrio by introducing quicksilver to the height of one inch in the shorter leg ; quicksilver being nearly fourteen times heavier than water. If the quicksilver be raised to two inches, it would balance a column of water twenty-eight inches high ; and so on.

Since, then, the pressure of fluids of equal densities is directly as their perpendicular heights, without any regard to their quantities, it appears that whatever the figure or size of vessels be, if they are of equal heights and if the areas of their bottoms are equal, the pressure of equal heights of water are equal upon the bottoms of these vessels ; even though the one should hold a thousand, or ten thousand,

times as much water as would fill the other. To confirm this by an experiment, let two vessels be prepared of equal heights, but very unequal contents, such as *A B* (Plate I., fig. 9), and *A B* (Plate I., fig. 10). Let each vessel be open at both ends, and their bottoms *D d*, *D d*, be of equal surface. Let brass bottoms *C C*, equal in weight, be exactly fitted to both vessels respectively, not to go into them, but for them to stand upon; and let a piece of wet leather be put between each vessel and its brass bottom, for the sake of closeness. Join each bottom to its vessel by a water-tight hinge *I*, so that it may open like the lid of a box; and let each bottom be kept up to its vessel by equal weights *E* and *E*, hung to lines which go over the pulleys *F* and *F* (whose blocks are fixed to the sides of the vessel at *b*), and the lines tied to hooks at *h* and *h*, fixed in the brass bottoms opposite to the hinges *I* and *I*. Things being thus prepared and fitted, hold the vessel *A B* (figure 10) upright in your hands over a basin on a table, and cause water to be poured into the vessel slowly, till the pressure of the water bears down its bottom at the side *d*, and raises the weight *E*; and then part of the water will run out at *d*. Mark the height at which the surface *H* of the water stood in the vessel, when the bottom began to give way at *d*; and then holding up the other vessel *A B* (figure 9) in the same manner, cause water to be poured into it at *H*; and you will

see that when the water rises to  $A$  in this vessel, just as high as it did in the former, its bottom will also give way at  $d$ , and it will lose part of the water.

The natural reason of this paradoxical phenomenon is, that since all parts of a fluid at equal depths below the surface are equally pressed in all manner of directions, the water immediately below the fixed part  $Bc$  (figure 9) will be pressed as much upwards against its lower surface within the vessel, by the action of the column  $Ai$ , as it would be by a column of the same height, and of any diameter whatever; and, therefore, since action and re-action are equal and contrary to each other, the water immediately below the surface  $Bc$  will be pressed as much downward by it as if it was immediately touched and pressed by a column of the height  $iA$ , and of the diameter  $Bc$ ; and, therefore, the water in the cavity  $BDdc$  will be pressed as much downwards upon its bottom  $CC$  as the bottom of the other vessel (figure 10) is pressed by all the water above it.

To illustrate this a little further, let a hole be made at  $f$  in the fixed top  $Bc$  (figure 9), and let a tube  $G$  be put into it; then, if water be poured into the tube  $A$ , it will (after filling the cavity  $Bd$ ) rise up into the tube  $G$ , until it comes to a level with that in the tube  $A$ , which is manifestly owing to the pressure of the water in the tube  $A$ , upon that

in the cavity of the vessel below it. Consequently, that part of the top,  $Bc$ , in which the hole is now made, would, if corked up, be pressed upward with a force equal to the weight of all the water which is supported in the tube  $G$ ; and the same thing would hold good at  $g$ , if a hole were made there. And so, if the whole cover, or top,  $Bc$ , were full of holes, and had tubes as high as the middle one,  $Ai$ , put into them, the water in each tube would rise to the same height as it is kept into the tube  $A$ , by pouring more into it, to make up the deficiency that it sustains by supplying the others, until they are all full; and then the water in the tube  $A$  would support equal heights of water in all the rest of the tubes. Or, if all the tubes except  $A$ , or any other one, were taken away, and a large tube, equal in diameter to the whole top,  $Bc$ , were placed upon it, and cemented to it; and then, if water were poured into the tube that was left in either of the holes, it would ascend through all the rest of the holes until it filled the large tube to the same height that it stands in the small one, after a sufficient quantity had been poured into it: which shows that the top  $Bc$  was pressed upward by the water under it, and before any hole was made in it, with a force equal to that wherewith it is now pressed downward by the weight of all the water above it in the great tube; and, therefore, the re-action of the fixed top  $Bc$  must be as great in pressing the water down-

ward upon the bottom  $CC$ , as the whole pressure of water in the great tube would have been if the top had been taken away, and the water in that tube left to press directly upon the water in the cavity  $BDdc$ .

After what has been said relative to the pressure of fluids, it is hardly necessary to say more, for the things, on mature consideration, must appear so plain, that to offer further elucidations would merely take up time without answering any beneficial purpose. We here remark, that the four foregoing propositions are fundamentally the same with what are given by Dr. Hutton in the second volume of his *Course of Mathematics*; and, that for the experiment to explain the equality of pressure in vessels of unequal capacity, but of equal heights, and having bases of equal area, we are indebted to the published lectures of the ingenious Mr. Ferguson. Under the sanction of two names so eminent in their respective writings for correctness and perspicuity, addition would be useless, explanation unnecessary.

When cast-iron tanks are required to be constructed for gas-holders to work in, it would be causing the manufacturer needless expense, should each tier of the upright curved plates, which form the sides of the tank, be of the same uniform thickness from the top to the bottom of the tank. For it has been shown in PROPOSITION III., *Corol.* 2,

that the horizontal pressures of a fluid vary directly as the depths at which they are exerted ; and, consequently, that the re-acting force (as *the strength of the side* of the vessel containing the fluid), which neutralizes the horizontal pressure, varies likewise in the same ratio. Tanks being at the present day very seldom made more than eighteen feet deep, and often less ; shallowness, for many reasons, being desirable, the iron-founder finds it expedient to cast, for their construction, rectangular curved iron plates ; and as there is a difficulty, amounting almost to an impossibility, in casting such plates when of large dimensions less than five-eighths of an inch thick, it is never done. The proportionate thickness of each tier of plates at different depths, as exemplified in the next sentence in practice, approaches near enough the theoretical truth (though double in result) for practice, as several contingencies are to be provided for, besides the necessity of strength sufficient for resisting the lateral pressure of the contained fluid, such as the action of chemical solvents, and accidental injury, &c. When a cast-iron tank is to be constructed, thirty-four feet in diameter and eighteen feet deep, the plates which form the bottom, being segments made by circles concentric with the great circle cutting sectors of the same, are about three-quarters of an inch in thickness. The plates forming the side, being portions of the great cylinder, are each about eight feet

in length and six feet in depth. The lower tier are seven-eighths of an inch, the middle three-quarters, and the upper five-eighths of an inch, in thickness. The breadth of the flanches round each plate is three inches and a half from the inside, and the thickness of the flanch is equal to the thickness of the plate. In putting a cast-iron tank together, the joints are made with iron cement and screw-bolts, in the way hereinafter mentioned for jointing flanch pipes. The screw-bolts are five-eighths of an inch in diameter: in the bottom and in the lowermost tier of the side-plates, they are placed about five inches asunder, in the middle tier of plates six inches, and in the upper one seven. The lowermost tier of plates is generally surrounded by three wrought-iron belts, the middle one by two, and the upper tier by one: these belts are made of the best iron, four inches broad and five-eighths of an inch thick, and keyed together, and then drawn tight by means of wooden wedges rising to the same height as the flanches upon the plates, by which an equal pressure upon each hoop is obtained in every part of its bearing.

It will be obvious to the reader, that the tank of which I have been speaking is a single vessel; and, therefore, in the construction of single vessels of larger or smaller dimensions, he will be able, from what has been said, to calculate upon the thickness of metal which he ought to use; but there has occa-

sionally been used a tank so formed as to exhibit its boundary lines in the plan by two concentric circles: the radius of the outer one being about nine inches more than the semi-diameter of the gas-holder, of the inner one about nine inches less. It is only between these that the water is introduced for the gas-holder to work in. This species of tank possesses some advantages over the former one, especially where water is not very plentiful. In it the interior range of plates will not require to be of so much strength as the exterior; it is, however, a mistaken notion, which leads some persons to suppose that the exterior plates might with safety be made more slight in this than in a vessel constructed on the ordinary principle, to be entirely filled with water.

Circular-shaped tanks are to be preferred to any other, for various reasons, amongst the most prominent of which are the uniformity of resistance to pressure at equal depths by every part of their upright surfaces, and the least surface with the greatest content; for, in square tanks the angular points will be liable to give way, and the making of such to contain the necessary fluid will be attended with difficulties which never present themselves in the construction of cylindrical vessels.

Formerly wooden vats were occasionally used in lieu of tanks for the gas-holder to work in, but of late years the practice has been discontinued, and it

is not likely to be again adopted. When they were used, the back-maker generally guaranteed the durability of the vat for some specific period; he was therefore careful to construct it of such materials and workmanship as to prevent, on his part, any failure in the terms of his contract.

Of late years the practice of making tanks for the gas-holder to work in, of brick-work or of rubble masonry sunk into the ground, has been very much followed; by which, where the ground is at all favourable, an immense saving of outlay is effected. The usual mode of constructing such tanks is to excavate the ground to a depth of about two feet deeper than it is proposed shall be the working height of the gas-holder; and for gas-holders of about forty feet in diameter, the excavation should be full fifty-two feet diameter at the top, sloping down so that it may be about forty-eight feet diameter at the bottom. When the ground is all got out, the entire of the bottom ought to be puddled over with well-tempered clay, to one foot in thickness, trodden and beaten with rammers when in its place. The inlet and outlet pipe, with the upright or rising parts jointed together, should be then fixed in their places, and have piers of brick-work or masonry laid in Roman-cement, built round them to the height of about three feet to keep them upright. When that is done, a circle of forty-one feet diameter should be struck, which will show the

situation of the inner face of the tank; and to it let a course of brick-work, twenty-two inches thick, be laid all round, except where an opening may be left, where the inlet and outlet pipes are brought in: carry up another course of brick-work of the same thickness, and upon that lay two courses more with an offset outside of about two inches. Then cover the openings which had been left for the inlet and outlet pipes, either by slabs or by turning arches over them. When this is done, let the entire of the bottom and the back of the walls be covered with puddle to the depth of another foot, so that the entire thickness thereof, with what had been already laid, shall be two feet. Next carry up the side walls to the height of six feet in eighteen-inch work, letting the workmen go on at the same time with the puddling at the back of the wall, in courses of not more than one foot at one time. This puddle should be put in very soft, so that a man in trampling it will sink nearly to his knees. The puddle should, to the height of six feet, not be less than eighteen inches in width, or so as to fill in between the back of the wall and the excavation entirely. The remaining twelve feet of the side walls should be of fourteen-inch work up to the level of the ground, and finished at the top with three courses of nine-inch brick-work, and a coping of three-inch Yorkshire flagging. In building this description of tank (which is supposed to be of

brick laid in lime and sand-mortar), the bricklayers will find it most convenient to work by movable trammels slipped over an upright centre pole or rod. The puddle is put in one foot in depth at one time, till the whole of the back of the wall, to the level of the ground, is completely filled in ; and, from its being put in very wet, by the trampling of the workmen it is forced into the joints of the brick-work, and into the pores of the bricks, so as entirely to prevent any escape of water from the tank. The upper twelve feet of the puddle may decrease in width from eighteen to twelve inches, with a regular batter ; but as it is put in, it must be filled in with ground well rammed in at the back of it, so as compactly to replace the ground which had in the first instance been removed. A tank of this kind is quite as trustworthy for holding water as a tank of cast-iron ; and may, where the circumstances as to ground are favourable, be constructed at one-half of the expense, or even less.

When tanks are constructed of rubble masonry, the walls must be made of about one-third greater thickness than where brick is used ; in all other respects the mode of procedure, as regards puddling, &c., what has been already spoken of relative to brick tanks, must be attended to, except that the excavation will have to be made of so much more diameter as the walls are of greater thickness. Sometimes a considerable saving may be effected

by leaving a core in the bottom of the tank, as shown in figure 5, Plate XV. For as the centre-casting, for securing the internal stays of the gas-holder, need never be of a length greater than two-thirds of the height of the gas-holder, it must be evident that, where a gas-holder eighteen feet in height is used, if ground or other matter be left remaining to the height of six feet at the middle of the tank, provided there be no obstruction to the distance of eighteen inches from the side walls all round the tank, to prevent the gas-holder from going down, it will work quite as well as if the bottom had been made so as to form a horizontal plane. The figure alluded to shows what the form of the bottom would be in such case, in which A A is that part of the ground which is not removed at all, and B B the puddle laid over it to staunch the bottom. In this case, as before, the walls must be built upon a bed of well-tempered clay one foot in thickness, not put in very soft; and the puddling at the back of the wall must be executed as has been already directed.

The next subject presenting itself to our notice, is the construction of gas-holders of such dimensions as are required in large manufactories. Those similar to figure 1, Plate XV., containing 15,000 cubic feet, are generally made of plate-iron, (number 16 wire-gauge, and weighing about 2 lbs. 11 oz. to the square foot,) riveted together with quarter-

inch rivets seven-eighths of an inch asunder. When gas-holders of magnitude first began to be constructed, they were encumbered either with a heavy wooden frame-work inside, which answered no useful purpose, or otherwise the interior was so loaded with iron stays, that it became necessary to use an immense balance-weight, thus removing one evil as it affected the pressure by introducing another. Experience has now taught the manufacturer that he cannot construct his gas-holder too light. Instead of the cumbrous wooden frame or weighty iron stays formerly used, that vessel consists now, in many instances, of nothing save the plate-iron riveted together, and angle-iron round the bottom and the top inside, for keeping it in form. Where gas-holders are used without being suspended by a chain or chains, and without any counterpoise, and simply being kept in an upright position by guide-rods, friction-rollers, &c., the above is the general mode; but when the gas-holder is suspended, and a counterpoise is used, whether the suspension be from the centre or from three or more points in the circumference, then light internal or external stays will be required for keeping it in shape. For this purpose, rods of three-quarters of an inch in diameter, of the best iron, will generally be of sufficient strength; but the arrangement of them, so as best to meet the strain upon the gas-holder, must be left to the gas-holder maker, who, from practice,

is the best qualified to dispose them in a judicious manner, according to the mode of suspension adopted.

As in most gas establishments, the gas passes through a machine, sometimes called "*a governor*," and sometimes "*a regulator*," after it has left the gas-holder and is on its way to the street mains (as will be hereafter described), and which so adjusts itself to circumstances as to keep the pressure upon the street mains uniformly the same, though there may be an inequality in the pressure of the gas-holder, the use of compensating chains, balance-weights, &c., are in this case not needed; but in works where there is no governor or regulator, the equable emission of the gas must depend upon the gas-holder exerting an equal pressure upon the gas therein, at all heights of its rise or fall. We therefore think it desirable, first, to show how to calculate the pressure of any gas-holder where compensating chains and balance-weights are not used; and, secondly, to ascertain what weight should be attached to the compensating chain to cause the gas-holder to work at some specific pressure. To find the pressure at which a gas-holder would work, supposing it unencumbered with weights and chains, but supposing it to be constructed as if to be used with such appendages: if the diameter and depth of the gas-holder in feet, the weight in pounds, of a superficial foot of the plate-iron of which it is con-

structed, and the extra weight for overlap, angle-iron, stay-rods and rivets, be given to find the pressure at which it will work; we first find the area of the top in square feet, by multiplying the square of the diameter by  $\cdot 7854$ . Then, to find the superficies of the sides, say, as 7 is to 22, so is the diameter of the gas-holder to its circumference; and the circumference thus found being multiplied by the height of the vessel, gives the area of the cylindrical surface, which, being added to the area of the top of the gas-holder in superficial feet, the sum will express the number of square feet of plate-iron required for constructing it, less and an allowance for the lapping over of the plates. Multiply the number of square feet of plate-iron, as above, required for constructing the gas-holder by the weight of one square foot of the material of which it is constructed, and to the product add the weight of rods, rivets, angle-iron, and an allowance for the lapping over of the joints; the sum will be the absolute weight of the gas-holder. Reduce the absolute weight into ounces, and the area of the top of the gas-holder into square inches, by multiplying its area in superficial feet by 144. Next, divide the weight in ounces by the area of the top of the gas-holder in square inches, the quotient will express the pressure upon every square inch in ounces. But, as we speak in other language, by saying the gas-holder works at so many tenths of an inch

pressure, if we divide the pressure upon each square inch in ounces by the weight of a cubic inch of water,  $\cdot 5787$ , the quotient will express the pressure in inches and decimal parts of an inch.

Hence, by proceeding as above, it will be found that a gas-holder of 15,000 cubic feet capacity, if made 33 feet in diameter and 17 feet deep, would weigh about  $3\frac{3}{4}$  tons, and would, if unencumbered with the compensating chain and balance-weights, work at  $1\frac{9}{10}$ th inch pressure, nearly throughout its rise and fall, whilst a gas-holder of 15,000 cubic feet capacity, if made so as to be 42 feet in diameter and 11 feet deep, though it would weigh about four tons, would, under similar circumstances with the former, work at about  $1\frac{1}{4}$  inch pressure nearly uniformly. On considering this matter, it will be seen that, as the diameter of the gas-holder is increased, supposing the plate-iron of which it is composed to be of the same thickness, the pressure decreases.

To ascertain what weight should be attached to the compensating chain to cause the gas-holder to work at some specific pressure, find the area of the top of the gas-holder in square inches, as in the former case, and multiply that area in square inches by the weight of one cubic inch of water,  $\cdot 5787$  oz., should it be desired to work the gas-holder at one inch pressure; by the weight of two cubic inches of water, or  $11\cdot 574$  oz., if it be desired to work at two inches pressure; or by  $\frac{11}{10}$ ths,  $\frac{12}{10}$ ths,

$\frac{1}{10}$ ths,  $\frac{1}{4}$ ths, &c., of  $\cdot 5787$ ; if it be desired to work the gas-holder at  $\frac{1}{10}$ ths,  $\frac{1}{2}$ ths,  $\frac{1}{3}$ ths,  $\frac{1}{4}$ ths, &c., pressure; this in each case will give a weight in ounces which, reduced into pounds, will show how much less the counterpoise should weigh than the gas-holder to which it is attached: for example, we will take a gas-holder 33 feet in diameter, as above, whose absolute weight has been stated as  $3\frac{3}{4}$  tons, or 8400 lbs.

The area of a circle 33 feet diameter is  $855\cdot 3$  superficial feet  $\times 144 = 123,163$ , the area of said circle in square inches:—we will suppose it is desired to work this gas-holder at  $\frac{1}{4}$ ths pressure;  $\frac{1}{4}$ ths of  $\cdot 5787 = \cdot 8102$  nearly  $\times 123,163$ , the area of the top = 99,786 oz., nearly = 6237 lbs.; which weight being supposed to be uniformly spread over the entire of the top of the gas-holder, must be deducted from the absolute weight of the gas-holder, the difference will be the weight of the balance-weight to be applied as a counterbalance. In this case the absolute weight of the gas-holder was stated to be  $3\frac{3}{4}$  tons or 8400 lbs., deducting therefrom 6237 lbs. as just found, leaves 2163 lbs., or 19 cwt. 1 qr. 7lbs., as the counterbalance when intended to work at  $\frac{1}{4}$ th pressure.

After what has been already said relative to the gas-holder, we shall first notice such as have been used, and then describe such as are generally adopted now. Square or parallelopipedal-shaped gas-holders

appear to have been much used in the early stages of gas-lighting. The objections against them having been already noticed, we will not add more here than that such are now very rarely constructed. These were followed by cylindrical ones ; but with encumbrances of internal wooden frames, or heavy iron stays, which so loaded them as to render their action very heavy. Soon after the cylindrical gas-holders had begun to be generally adopted, Mr. Clegg invented and put up a gas-holder at the Westminster gas-works, with a rotary or revolving motion, which remained in action for several years ; but it has long since been taken to pieces, so that there is no gas-holder on that plan now in use, nor is it at all probable such a one will be again put up, as the telescopic gas-holders answer all the ends it was intended to answer, at much less expense, and in a more simple manner. We have had several plans laid before us for constructing gas-holders to work with air-vessels, instead of regulating the pressure by means of a compensating chain or weight ; but very few of them were ever tried, and when they were so, their action and cost being taken into consideration, it was found they offered no advantages such as could warrant their general adoption ; it is, therefore, at this time unnecessary to give any description of them. Another kind of gas-holder, called the "Collapsing gas-holder," was several years ago invented by Mr. Clegg, it worked in a very shallow tank, into which the lower

edges of its sides and ends were immersed. It occupied a much greater area of base than any of those we have mentioned. When it was full of gas, the end view was represented by an equilateral triangle, the bearings being from the angle opposite to the base. This gas-holder was so constructed that the sides had a tendency to close with each other, and therefore when the valve of supply was open, such tendency expelled the gas. In such a gas-holder it is evident that certain parts of each end required to be constructed of a flexible material, to get that to withstand the action of the gas, and to remain perfectly without cracks or other fissures, were insuperable objections to its use. Many years before the telescopic gas-holder, now so much used, was thought of Mr. William Stratton, of Gutter-lane, Cheapside, obtained a patent for a kind of double gas-holder. One of the objects he had in view was doubling the capacity of the gas-holder (or nearly so) without increasing the dimensions of the original tank, in works where it might be requisite for want of ground to turn it to the best account (particularly where the demand for light had increased beyond the expectations of the manufacturer); in such cases he supposed it would be worthy of attention. The invention did not, however, come much into use. The tank he prepared was formed of two upright ranges of cast-iron plates, at about two feet asunder, connected together by plates at the bottom. When this tank

was filled with water, it formed a ring of water, into which the gas-holders dipped. This arrangement required two gas-holders, of which more will be said hereafter. The tank was supported upon piers of brick. Within the interior circle of it was a space equal to the diameter of the internal ring, and equal also in height to the height of that ring which might be used for the reception of castings or other heavy stores. The entrance and exit pipes of gas-holders constructed on this principle were situated between the interior and exterior upright plates of which the tank was formed, and rose between the two gas-holders which were bulged out for the purpose. At equal distances round the tank were placed four columns for supporting a semi-circular shaped frame. Upon this frame were placed two carriages for supporting grooved wheels, over which the gas-holders were suspended.

For a tank of eighteen feet in depth, the outer gas-holder was about thirty-five feet in depth, and the inner one about seventeen feet six inches. At the centre of the top of the outer gas-holder was a stuffing-box, through which was introduced a cast-iron pipe of three or four inches in diameter, with a broad flanch at the bottom, through which it was bolted to the centre of the top of the inner gas-holder. To the upper end of the same pipe was fastened the chain which passed over the grooved wheels just mentioned, the opposite ends of which chain were

attached to the top of the outer gas-holder, so that the interior gas-holder acted as a balance weight to the exterior and *vice versâ*.

If we suppose this double gas-holder to have been empty, it must appear evident that the outer one would have risen about seventeen feet six inches above the tank, and the inner one to very nearly the same height. If then the gas has been allowed to enter, the outer gas-holder would have risen, and as it did so, the inner one must of necessity have descended, because they were connected together by the suspending chains, and therefore the inner one would sink as much as the outer one rose: so that when the outer one had risen seventeen feet six inches, the inner one would have descended through a like space, and then there would be a distance of thirty-five feet between the upper surface of the top of the inner gas-holder, and the inside of the top of the outer gas-holder. Such space would have been occupied by gas, thus nearly doubling the capacity of the vessel acting in a tank of the same diameter and depth as when a single gas-holder was used. The centre supporting pipe which has been mentioned was open both at its top and bottom, so that when the double tank was used, there could not be any apprehension of a lodgment of gas beneath the lower gas-holder, as from its levity it would be sure to escape through that pipe should any leak take place in the top of the interior gas-holder. The

gas-holder of which we have been speaking was well adapted for producing a regular pressure at all heights of its rise, without the compensating chain and balance weights usual in the other constructions; for by considering the nature of the arrangement, it will be evident, that as one vessel rose out of the water the other one descended into it; so that if it had been constructed to work at a given pressure at one height, it would uniformly have maintained such pressure at all other heights of its rise or fall.

Were all the different kinds of gas-holders but briefly described which have from time to time been submitted to the notice of the gas-light manufacturer, much space would be taken up and no useful end attained, we therefore propose to bring this chapter to a close by describing those three or four only generally used now, concluding with the telescopic, any one of which will very well answer the purpose of the gas-light manufacturer.

Plate XV., fig. 3, is a vertical section of a gas-holder, working upon a centre column in a brick tank. We will suppose the gas-holder in this case to be eighteen feet deep,—when of that depth the centre column marked A A should be about forty feet in height, and three feet six inches in diameter inside, (clear of the inside flanches not shown in the figure, the scale being too small, by which it is bolted and joined together,) and may be cast in lengths of ten feet each. The lowermost flanch of the bottom

piece being cast very broad and strong for the purpose of being bolted to a casting laid beneath a base of brick-work laid in Roman-cement, and through which casting and brick-work the bolts pass, as well as through the flanch just mentioned, so that all are screwed up together so as to form a compact and very heavy mass, and thus afford security to the column. The flanch at the upper end of the bottom piece of the column, as well as the flanches of the pieces above it, and at the lower end of the uppermost piece, are cast inside, so that the exterior surface of the column may present a vertical surface without any projections from top to bottom. The top of the uppermost piece of the column may be cast with a bold broad moulding outside, and with a face at the top for the carriages to stand upon, which support the three pulley-wheels C, D, E, by the chains passing over which the gas-holder E E and the balance weight G are suspended. The column is jointed together by means of bolts and nuts, and rust-cement; it must be constructed so as to be perfectly water tight to the height at which the water stands in the tank, which is represented in this figure by the dotted line B B; the upper part may be cast in open work, which will save weight in the castings, and give the column a lighter appearance. There will be seen, on referring to the figure at the centre of the gas-holder, and forming a part of it, a cylinder of plate-iron of sufficient diameter inside to slide up

and down with the least friction against the internal column; at the top of which cylinder, and connected also with the top of the gas-holder F F, is fixed a very strong cast-iron ring, through which, and through the top of the gas-holder, as well as through the angle iron of the cylinder we are speaking of, pass three eye bolts, to which is attached one end of each of the chains which pass over the pulley-wheels and meet inside the column, where they are secured to the balance weight G which rises and falls therein as the gas-holder is depressed or elevated.

A gas-holder for working with an upright centre column may be constructed of No. 16 wire-gauge plate-iron; but the small cylinder which works upon the column ought to be at least of No. 12 wire gauge, for if lighter, it is apt, by friction against the column when pressed close thereto by action of the wind, particularly when very high, to be very soon injured, and hence to become leaky; to prevent which every precaution should be taken, as from the situation of that part of the gas-holder it would be difficult to repair without discontinuing to use it, and emptying the tank. This is a great objection to the use of the centre column mode of suspending gas-holders, so much so, that now they are very seldom constructed on that plan. This kind of gas-holder being suspended from near its centre, requires the internal stays and braces to be of nearly similar arrangement to that adopted in gas-holders suspended from their

centre. H represents the inlet, and I the outlet pipe; J J J J J brick-work of which the tank is composed; K K K K K puddle under the bottom and round the walls of the tank. This mode of suspending gas-holders was invented by Mr. John Malam of Hull, who put up several thereafter; and on the same plan several were put up some years ago by different gas companies.

*Plate XV., Figure 4*, is a vertical section of a gas-holder suspended from four or more points of its upper circumference, and represented as working in a brick-tank. For a gas-holder of forty feet diameter four points of suspension are sufficient, but in larger gas-holders it is well to have six or even more points of suspension. In figure 4, it is supposed that the gas-holder is forty feet diameter, and that it is suspended from four equidistant points, (plans of two such gas-holders marked N and O is represented in Plate VI.); A B represent two cast-iron columns each about fourteen feet high, secured to the top of the tank by means of screw-bolts, each three or four feet in length, which are built in the brick-work forming the walls of the tank, and pass through a stone at their lower end, so that when the nuts above the bottom flanch of the column are properly screwed up, the columns stand quite firm and in a perfectly vertical position. There are two other such columns so secured (see plan already referred to) which are not shown in

this section. On the top of each column is fixed a carriage for supporting the pulley-wheels, (as C and D on columns A and B), over which run the chains which suspend the gas-holder and support the balance-weights E and F. For causing the gas-holder to work vertically and for preventing it from being shaken by the action of the wind, there is attached to each column a rack about six inches greater in length than the gas-holder is in height, in each of which works a pinion connected to a shaft, as G G, which passes through the box H, secured to the centre of the top of the gas-holder. As the pinions are fixed and keyed to the ends of the shaft G G, (which is in one piece or connected by couplings,) it is evident that in whatever direction one pinion moves, the other must necessarily move in the same, in the racks attached to the pillars A and B; therefore if two other pillars were fixed with racks attached to them, so that another shaft similar to G G should pass through the box H so as to be at right angles with G G, the pinions at the end of this second shaft would act in their respective racks similarly and simultaneously with the pinions at the ends of the shafts G G; consequently, as the gas-holder rises or falls, the pinions turn equably in one direction or in the reverse, and so keep the top of the gas-holder perfectly level and its sides always vertical, thus rendering guide-rods or friction-rollers unnecessary. Though not absolutely necessary to

furnish each of the four pillars with pulley-wheels, suspension-chains, and balance-weights, it is found in practice better to do so, for gas-holders of forty feet diameter, when suspended from two points only, are liable to sag and get out of form, from the force of gravity acting unopposed upon the gas-holder in the great interval between the two points of suspension, which is not the case when they are suspended from four points. When gas-holders of sixty feet diameter (or of a larger size) are worked on this plan, instead of the shaft G G passing quite across the top of the gas-holder from the rack on the column A to the rack on the column B, it is found more convenient that the box H should be made about three feet six inches diameter inside, so that a bevel-toothed wheel of about three feet diameter can work therein horizontally. In this case, the shaft proceeds from the rack attached to the column A, &c., to the box H, and from the rack attached to the column B, &c., to the box H at the end at A B, &c., are fixed and keyed pinions as already described; but at the end of both of the shafts which enter into the box H, are fixed and keyed bevel pinions which simultaneously work into the bevel-wheel therein contained, and consequently the bevel pinions and the common ones all move at the same speed upon the bevel-wheel and into the teeth of the respective racks, producing precisely the same effects as if there were a shaft G G all of one

piece. The shafts *G G* or *G H* will in all cases have to be supported upon carriages bolted upon the top of the gas-holder at about ten feet from each other, to prevent the shaft from sagging and to cause the pinions to work freely in their respective racks, &c. The carriages should each have a coupling over the shaft to keep it in its place as the gas-holder goes down. The nearer to the circumference of the gas-holder one set of carriages can be fixed the better, so that there may be as short a distance between them and their respective racks as possible, in order that the intermediate part of the shaft should not be bent or twisted, for should such happen from any heavy gust of wind or from any other cause, the pinion would not work freely in the rack, and hence an unsteady motion would be produced. The gas-holder, *b c d*, forty feet diameter and twelve feet deep, is usually made of No. 16 wire-guage plate-iron. The internal stays radiate from the lower end of a flanch pipe about eight feet in length (the top end of which is secured to the crown of the gas-holder below the box *H*) to the angle iron which connects the top with the sides of the gas-holder as at *a c*, and also to the angle iron at the bottom as at *b d*. In a forty feet gas-holder there are about twelve such stays, each of three-quarters-inch round iron, radiating from the bottom of the centre flanch pipe to the uppermost angle iron, and the same number placed alternately ra-

diating from the same centre to the angle iron fixed at the bottom of the gas-holder. The dotted line *ee* shows the height at which the water stands in the tank; *II* the tank; *J* the inlet, and *K* the outlet pipe; *LL* the side wall of the tank, which in this figure is shown as if executed in brick. The bottom of the tank *MM* is also represented as of brick, it may, however, be formed simply of clay, well tempered and worked with rammers, so as to present a horizontal surface; or it may be made of the form shown in figure 5 of this plate, as may be thought most expedient. *NN* represents the puddle round the vertical walls of the tank, and *OO* well-tempered clay laid for the bottom to rest upon. For gas-holders of this description, a great number of which have been fixed, Mr. John Malam, of Hull, took out a patent in the year 1823.

*Plate XV., figure 5*, is a vertical section of a gas-holder suspended from three equidistant points of the circumference by chains passing over pulley-wheels fixed upon carriages on a triangular bridge, and also of a brick-tank for the gas-holder to work in. *Figure 6 of Plate XV.* is a plan of the same, in which corresponding parts are marked with corresponding letters of reference. In *figure 5*, *GG* represents a section of the tank. *FF* are the side walls supposed to be built of brick laid in lime and sand mortar. *AA* represents a part of the ground which had not been disturbed when the excavation

was made and which is represented as covered with well-tempered clay to a thickness of two feet as at B B B B, upon which the side walls F F are built. B B at the back of the side walls is to be well grouted in with thin puddle well trodden down, as has been already directed, till it reach the level of the ground. The inlet and outlet pipes for the gas are not shown in this figure; but they must be fixed in precisely the same way as that shown in the description of figures 3 and 4 of Plate XV. In carrying up the side walls, it will be necessary, when they come to within about three feet six inches of their height, to build in four stones in the situations in which the four columns *a, b, c, d* stand, with holes made through them, to correspond with the bolt-holes cast in the bases of the columns marked *a, b, c, d*, or four cast-iron plates of the same size as the said bases, and with holes cast in them to correspond with the holes cast in the bases of the columns. Through each of these stones or plates are to be passed four three-quarter-inch screw-bolts, with their heads underneath the plate or stone round which the brick-work is to be built, each set of bolts being kept in its exact position by a trammel made for the purpose, so that when the pillars *a, b, c, d* are fixed in their places, the holes in the flanch of the base of each respectively shall receive the bolts over which each is to be placed and secured thereto by nuts working upon the upper part of its bottom

flanch or base, so that when the nuts are screwed up, the plate built into the brick-work, together with the brick-work between that plate or stone and the column, shall be inseparably connected together and form as it were one compact and solid mass. The columns *a*, *b*, *c*, *d* are to stand in a proper position for supporting the frame C D E H, (shown in plan at figure 6,) and which frame must admit of the small pulleys *f*, *g*, and *h*, (figure 6,) allowing their respective chains to fall just within the circumference of the top of the gas-holder, and so as to divide that circumference into three equal parts in order that the points of suspension may be equidistant one from the other. If they be so, it is evident that if the chain of suspension which passes over the pulley-wheel *g* (figure 6) be brought over the pulley-wheel at *d*, and be sufficiently long to be connected with a shackle to the horizontal part of the balance-rod, (which in this case is T-shaped,) if the chain which passes over the pulley-wheel *h* (figure 6) in like manner be brought over the pulley-wheel *e* and connected to the horizontal part of the balance-rod, and the chain which passes over the pulley-wheel *f* (figure 6) be also passed over the pulley-wheel nearest to E, and connected to the middle part of the T balance-rod, the upper part of that lying perfectly horizontal when the chains are all tight and the top of the gas-holder is level, in whatever degree the gas-holder may rise or fall, the

top will always maintain a horizontal and the sides a vertical position ; for, the three chains from the three points of suspension being all connected to one weight, as that weight rises or falls so must also the points connecting it by means of the chains with the three points of suspension, below which is the centre of gravity of the gas-holder, hence there need be no apprehension of the gas-holder itself having a tendency to alter its motion from that of a direct rising or falling one. Where gas-holders suspended in this way, however, are erected in the open air, it will be desirable to place friction-rollers in carriages built into the side walls of the tank about four inches below the level, at which the water is proposed to stand to prevent any oscillatory movement from the influence of high winds. These friction-rollers may be about six inches in diameter and four inches wide on the face working against the side of the gas-holder. They should be placed at not less than ten feet nor more than fifteen feet asunder. The columns *a*, *b*, *c*, *d* may be of cast-iron or built of brick (as square piers) as may be most advisable, though iron is the better of the two materials, giving a more workmanlike finish and costing very little more than brick. The columns should be about two feet higher than the utmost rise of the gas-holder, in order that the top of the gas-holder, which is always made of a convex form outside, may not, when the gas-holder is at its height, touch the

triangular frame C D H (figure 6). C D E represents the depth of the triangular frame, which will of course vary according to the length of the pieces C, D, and H, figure 6. For a gas-holder of from twenty to thirty feet diameter, if made of good Baltic timber, the pieces of which it is composed need not be more than twelve inches deep by four inches in thickness. *ijkl* is a section of the gas-holder which must be furnished with internal stays similar to those mentioned in the description of figure 4, of Plate XV. The pulleys, wheels, chains, and balance-weights are not shown in this figure, but the situation of the former are shown upon figure 6. The three chains meet at E, (figure 6,) which is the situation of the balance-weight.

*Figure 6, Plate XV.* is a plan of figure 5 of the same plate upon which the corresponding parts are marked with similar letters of reference, consequently very little remains to be explained here, beyond noticing that the sides of the triangular frame are kept from warping by the blocks placed between them in the situations marked \*\*, which blocks are kept in their places by  $\frac{5}{8}$  screw-bolts and nuts, two of which pass through each block and through the adjacent parts of the bridge, where they are screwed by their nuts upon square washers of iron. For security, it will be well to strengthen the angles at *a* and *c* of the frame by wrought-iron braces or clips to lap over at each side about nine

inches, each brace or clip should be about four inches broad and  $\frac{3}{16}$  of an inch in thickness. These should be secured to the frame by two-inch wood-screws through holes countersunk in the plate for receiving their heads. This mode of suspending gas-holders answers exceedingly well for small works, for which it is generally to be preferred from its small cost and the steadiness with which it works. It may here be remarked, that, as there are three compensating chains used in gas-holders of this kind when finding the weight per foot of each chain, the three must be considered but as the weight of one, which being found as directed at page 271, one-third of that will be the weight of each of these; so where four chains are used, divide the weight so found by four, where six by six, and so on. We have been very full in our explanation of the mode in which this gas-holder is suspended and acts, because the large telescope gas-holders now so generally used in London and in several other large gas establishments are suspended from three points at their circumference in a similar manner as this is: the chief case of difference between the two modes being merely that the triangular frame in which the pulley-wheels work is for adequately supporting the weight of the uppermost of these large gas-holders, constructed of bridges of iron, cast in pieces and with open work; and, when bolted together, each bridge, in its upper and lower

outline, is of the shape of a common parabola, the form of curve most suitable for the beam to have, in cases like this, where the weight is applied to any one given point thereof.

We have already had occasion to mention that the idea of doubling in one tank the capacity for gas of the gas-holder working into it had been acted upon, many years ago, by Mr. Stratton, and although his plan was never extensively brought into use, yet we consider that a modification of it might be advantageously carried into effect, being of opinion that his gas-holder might be so constructed as to answer quite as well, if not better, than the telescope gas-holders we are now about to describe, and with a much less expense of erection. In speaking of telescope gas-holders, we must remark, that some of those which we have noticed and seen described, and pointed out as vast improvements, we think highly objectionable, particularly those in which three or more gas-holders are suspended from pulley-wheels placed on the tops of columns with but one set of balance-weights to meet all contingencies. With respect to those in which three gas-holders slide one within another, we have no hesitation in affirming that, supposing the uppermost (or outside) gas-holder to be forty-five feet diameter and the chains and balance-weight adjusted, so that till the groove formed by the turning in of the iron at its lower edge, for the purpose of forming an hy-

draulic joint rises to the top of the water, it should work at  $\frac{1}{10}$  pressure, it will no sooner have that groove with the water, which will be lifted up with it clear of the water in the tank, than the pressure will be increased to between  $\frac{1}{10}$  and  $\frac{1}{8}$ , owing to the quantity of water that groove will contain and the extra iron used for forming the bottom and sides of the said groove; again, when the bottom of the second gas-holder rises above the water in the tank, a like increase of pressure will, for the same reasons, take place, so that then the pressure will have been increased from what it was originally,  $\frac{1}{10}$  to between  $\frac{1}{7}$  and  $\frac{1}{6}$ . That such will be the case may easily be ascertained, by finding the weight of water contained in each groove, and the extra quantity of iron for forming that groove, making an allowance for rivets, &c. The gross sum in ounces being thus ascertained, the pressure in tenths of an inch can be found by the method already described. The pressure is also found variable in the way described in practice, and hence, where but one gas-holder is used in a manufactory, the telescope one is to be objected to, unless a governor or regulator be used between that gas-holder and the main pipe of supply. Where several telescope gas-holders are used, the evil of inequality of pressure, may, to a certain extent, be remedied by working from two or three at the same time, having always one gas-holder at work at the greatest and one at the

lightest pressure; this contrivance, however, will not entirely counteract the evil we are speaking of. More effectually to obviate this variability of pressure, it is now the practice to have two sets of balance-weights and chains where there are two gas-holders working in one tank on the telescope plan, one set to each, three where there are three, and so on, as described by figures 1, 2, and 3, Plate XVI.

*Plate XVI., figure 1*, represents a vertical section of two gas-holders working into one tank on the telescope plan, with a section of a cast-iron tank and an elevation of the pillars for supporting the triangular frame, from which the upper gas-holder and its balance-weight are suspended by chains passing over the pulley-wheels fixed upon the said frame. In *figure 1*, A A A A represents in section the tank, B B the side plates, C C bottom, made of cast-iron plates, as has been already described, D D D pillars of brick-work laid in Roman-cement. each built upon a cast-iron plate, with holes cast in it for receiving bolts intended to secure the bases of the columns E F, G H, I J. The bolts passing through the bottom plate and through the brick-work, pass also through holes cast in the base of each column, when the nuts are screwed up so as to connect the bottom plate, the brick-work above it and the base of the column firmly together, and thus to afford to each column the required stability.

At the top of each pair of columns is a cast-iron box, as K K K in the figure, to which boxes the upper ends of the lower columns are secured and kept in their position; these boxes serve also as bases upon which to secure the second range of columns L M, N O, P Q, which again are surmounted by the cast-iron boxes R R R; these, in addition to the purpose answered by the boxes K K K, serve also for securing the carriages S S, upon which are supported the pulley-wheels T T T. These pulley-wheels have each their compensation chain, which is attached to the top edge of the lower or outer gas-holder, and to a balance-weight which comes into action when the trough at the bottom of the upper gas-holder rises out of the water in the tank, thus preventing the extra pressure arising at that point whenever the gas-holders are not provided with a second set of balance-weights. The upper tiers of columns have boxes above them similar to those already described, upon which rests and is secured the triangular frame C C, D D, E E, whereon are fixed the pulley-wheels *a, e, d, c, b*, over which pass the chains (shown by dotted lines) for suspending the upper or interior gas-holder. These chains all meet and are connected to the T balance rod, below the outer groove of the pulleys *e, d, c* (not shown in the figure). As the mode of suspension of this description of gas-holder is similar to that of the gas-holder shown at

Plate XV., figures 5 and 6, it will not be necessary to dwell further upon it in this place.  $efgh$  is a section of the upper or interior gas-holder,  $ii$  its top ; its bottom is represented by the dotted line  $jj$ .  $abcd$  is a section of the lower or exterior gas-holder, it is without a top, but the upper edge of its sides or ring is represented by the dotted line  $kk$ , and its bottom by the dotted line  $ll$ .  $**$  show the situation of the trough formed round the outside of the top gas-holder (as shown more at large at figure 3, where the same parts are marked by similar letters). To ensure the inner and outer gas-holder working freely together, it will be well to fix small friction-rollers (about ten feet apart) on the upper edge of the outer one, at the part where it is turned over, to work against flat vertical bars fixed on the outside of the inner gas-holder, by which means the sides are kept equidistant and parallel to each other at all heights of their rise and fall. We shall now suppose that the gas-holder we are speaking of is quite empty—in such case both the parts of which it is formed will be immersed in the tank, so that the top of the inner one  $ii$ , will be about an inch and a half above the water in the tank, and the bottoms of both the inner and outer one will rest upon the bottom of the tank. On the gas being allowed to enter by the inlet pipe (not shown in the figure), the gas-holder  $efgh$  rises or is lifted first till its lower edge  $jj$ , and the trough at  $e$  and

*h* rise just out of the water in the tank. So soon as that is the case, the weight passing over the pulley-wheels T T T come into action, and sustain the additional weight caused by the water in the trough, and the iron of which that trough is formed, consequently no additional pressure is thrown upon the gas-holder. The gas-holder continues to rise till it is in the position shown in the figure, and ultimately till the lower edge of the outer gas-holder *a l l d* has a dip of about two inches only in the water of the tank; in that position the inner and outer gas-holders are both full. In emptying the telescope gas-holder, the outer or bottom one will sink into the water contained in the tank first, and consequently will be the first emptied by the exit pipe (not shown in the figure). It is evident that telescope gas-holders ought to be made very true, so that the trough shown at \* \* should always be perfectly horizontal; for, supposing the trough to be six inches deep and three inches wide, if the gas-holder be of forty-five feet diameter, a very slight deviation from the horizontal plane upon the entire base would cause the trough to be nearly empty at one side (and thus allow the gas to escape where there was no hydraulic joint formed), whilst it might be quite full of water at the other. Great care is also needful in order to suspend telescope gas-holders, so that the top shall be always perfectly level and the side vertical.

*Figure 2, Plate XVI.*, is a plan of figure 1 of the same plate, showing the plan of the gas-holder and tank, and of the triangular bridge and pulley-wheels, also of the brick pillars (which are built outside of the cast-iron tank, and with their upper surface level with the bottom of that tank) for the pillars EF, GH, IJ to stand upon. To give greater stability to the triangular frame, it may be strengthened by the cross braces marked \*\*, in addition to the blocks shown between CC and DD, as was fully described in referring to figure 6, Plate XV.

*Plate XVI., figure 3*, shows in section a portion of the top and side of the gas-holder *efgh*, and also a portion of the side of the gas-holder *abcd*. This figure is given in order to show more clearly the lap-over of the interior upper one for forming the trough holding the water, into which the lap-over of the outer or bottom one dips, and so forms an hydraulic joint as at *h\* c*.

We conclude this chapter by remarking that the water in the tank in which the gas-holder works does never require to be changed or renewed, though this has been often unreasonably thought necessary: only what is lost by evaporation has to be replaced, which is very trifling at all times: and even in summer, when the gas-holders are fixed in the open air, the deficiency thereby occasioned is generally replenished by occasional showers, the tank receiving

all the rain which falls upon the top of the gas-holder. It will always be desirable to fit a waste pipe in each tank to prevent the water rising too high from heavy rains, which might cause it to flow down the inlet and outlet pipes, and thus stop the gas-way to and from the gas-holder, till such water was pumped out of the syphons or receiver attached to each gas-holder elsewhere explained. Should a brick or stone tank happen to be leaky, but which, if proper precautions be taken in their formation they rarely will be, the loss by leakage must of course be made good, or the gas-holder cannot be worked to its full extent; for how muchsoever the top of the gas-holder rises (when quite down) above the level of the water in the tank, so much gas room is lost in working it, as in that portion of it the gas cannot be expelled. We have very recently seen it very gravely asserted in print, that the surface of the water in the tank for the gas-holder gets covered with a stratum of coal-oil a few inches deep, which prevents the evaporation of the water, and allows the gas in the gas-holder to be saturated with this volatile substance so as to increase its illuminating powers. That such should be the case is entirely beyond our comprehension, and altogether at variance with full twenty-five years' extensive practice, during which period we never observed any such deposit; a thin pellicle of coal-tar formed from the redundant tar from off the tarred coating

of the gas-holder being nearly all that ever rests upon the surface of the water in a tank, the gas-holder in which never contains gas ineffectually refrigerated and purified : as to the gas being rendered of more illuminating power by being impregnated with the volatile particles of a stratum of naphtha supposed to be floating on the water within the gas-holder, we can only say that, so far from that seeming to be the case practically, the illuminating power of the gas is as greatly deteriorated by being kept for a time over this supposed volatile inflammable oil, as by being confined in any other close vessel.

## CHAPTER XII.

On various kinds of Valves, Syphons, and Tar-Wells.

THE necessity of adopting effectual means for shutting off all communication between the gas-holder and the street mains, as well as from one main pipe to another, under their various ramifications, pointed out the necessity of using valves of one description or another. Various descriptions of valves have been, and still are, used by the gas-light manufacturer ; but, for most purposes, the ordinary slide valve answers as well as any other. It is easily managed, and is particularly applicable to the main pipe of supply, as thereby the pipe can be opened to the full extent of its bore, or only partially, as may be requisite, according to the quantity of gas which may be necessary to pass through it in a given time—a thing which cannot be accomplished, either by the hydraulic or by the pneumatic valve.

*Plate XVII., figure 1*, is a vertical section of an hydraulic valve, particularly useful in the connexions upon the works. It is cylindrical, with a flanch at its top and bottom, and cast with a flanch quarter-bend projecting upwards from one side of it. At the bottom is bolted and jointed a double

cup, which rises to the lower part of the quarter-bend just mentioned. Through the centre of this cup is an opening of the same diameter as the bend. This centre part projects a few inches below the bottom of the valve, and is furnished with a flanch for jointing it to the pipe which brings the gas into the valve. Through the bottom of the valve is brought a wrought-iron bend, as shown in the figure, which is connected to an upright pipe of the same material, which rises as high as the top of the valve, and is for the purpose of introducing water into the inner ring of the double cup, the outer cylinder of which, being bored near its bottom, allows the water to pass into the outer ring. The top of this supplying pipe is covered by a cap, which is kept screwed on, save when it may be necessary to furnish a supply of water. The top of the valve is covered with a blank flanch, which is jointed and secured thereto by screw bolts in the usual way. At the centre of the top is fixed a stuffing-box, the bottom of which is tapped for receiving the square-thread lifting screw. The lifting screw is surrounded by a wrought-iron case, with a thread inside for the thread of the lifting screw to work in. This case, or female screw, is movable in the stuffing-box, and of sufficient height to work the lifting screw to the greatest height that may be required. It is made with two projecting handles outside, which serve as a wrench for raising or

lowering the screw. The bottom of this screw is secured to a double inverted cup, as shown in the figure, and therefore that is lifted or lowered with it. The inverted cup is so constructed, that when let down it falls between the two cylinders forming the lower one; and thus, if we suppose the bottom double cups to be nearly filled with water, and the upper one immersed in it, it follows, that a valve so constructed is capable of sustaining double the pressure of one made with but a single cup. At the same time we may remark, that the double cup valve, equally effective with the single cup valve, will not occupy much more than half the room. *Figure 2* is a plan of this valve, which, from what has been said, does not require further description.

*Plate XVII., figure 3*, is a vertical section of a pneumatic valve, which, from the stuffing-box at the top to the step for the spindle at the bottom, is rather more than twice the diameter of the main on which it is intended to be used. The body of the valve is square, as shown in the plan, *figure 4*, A few inches from the top, at one side, is cast a socket, and in a direct line therewith, at the other side, is cast a spigot, in order that it may be introduced into the range of main pipes wherever required. The inner faces of the socket, as well as of the spigot, project about an inch inward, and require to be chipped and filed, so as to present perfectly plane and smooth vertical surfaces.

Through the top of the valve, which is fitted with a stuffing-box, is introduced the spindle, so that the lower end of it rests in the step at the bottom of the valve, and the collar beneath brass couplings in the bottom of the stuffing-box, so that when the stuffing-box is fitted and the gland bolted down, should the wrench, or key, be applied to the square top of the spindle, the spindle will turn freely round, but without being raised. If, then, we suppose the valve to be open, as shown in the figure, there will rest upon its bottom two wedge-shaped pieces of iron, with their points downwards, and between them a third piece, also wedge-shaped, with the apex cut off. The spindle passes through the latter, which is fitted with a screw for receiving it, and it is thereby raised or lowered, as the valve may require to be shut or opened. Upon the centre piece, at a convenient distance from the top, is bolted a spring, which is also connected to the side pieces, so as to act between the top of them and the bolt which secures it to the middle piece. In its natural position, this spring has a tendency towards drawing the side pieces together, and of pushing the middle one downwards. This contrivance allows the three pieces to be lifted together, without the outer ones rubbing against the inside of the valve till they touch the top. The further ascent of the outer pieces being then arrested, the middle one continues to be raised by the screw till they are

completely wedged up against the interior of the socket and spigot, and as these wedge-shaped pieces are faced with cork or leather, the pressure can be carried to such pitch as ensures a gas-tight joint upon each. When the valve is in such position, the spring will be elongated horizontally, and so remain till the spindle is turned for lowering the interior pieces, when it again resumes its former shape, and thus draws the side pieces towards each other, and pushes the middle piece downwards. *Figure 4* is a plan of *figure 3*. It exhibits the flanch to which the top is to be secured, the socket and spigot shown in *figure 3*, and the top of the inner pieces, with the facings of cork. This is an effective and simple valve, of small size, and can be got up at a very trifling expense when compared with others more commonly adopted.

“*Syphons*” and “*Tar-wells*” (but why either should be so called we could never learn) we are next to mention: the former are of two kinds; the larger size are distinguished by their diameters, two, three, or four inch, &c., syphons; the smaller, which are used on the service pipes, are generally termed “*gun-barrel syphons*,” or “*bottle syphons*.” The shape of the vessel itself is similar in each case, but the furniture and use are different. The larger sized syphon is a cast-iron cylindrical vessel, of about a foot in depth, and of the diameter inside which corresponds with its distinguishing name. It has a

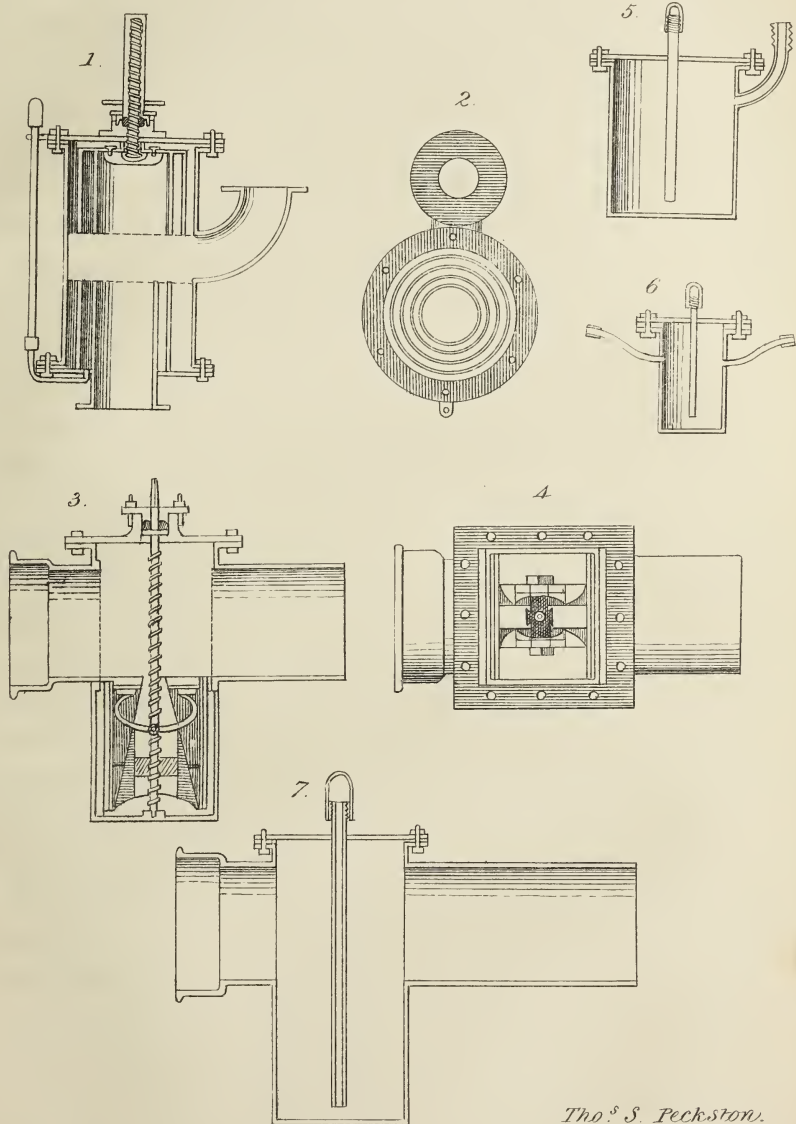
flanch round the top, to which is bolted a blank flanch, which forms its lid, generally with a paste-board flanch well soaked in linseed-oil, and with a coat of white-lead laid on each side of it, between the lid and flanch of the syphon through which the bolts for securing the lid pass, so that when the nuts are screwed up, a gas-tight joint is formed: or the joint may be made with iron-cement in the usual way. Through the centre of the lid (which is generally cast with a boss upon it) a hole is drilled and tapped for receiving a piece of three-quarter-inch wrought-iron tubing, which descends to within about two inches of the bottom of the syphon, and rises about three inches above the lid. Another piece of iron tubing, of an inch or an inch and a half in diameter, of the form of a bend, is screwed into a hole drilled and tapped into the side of the syphon (as shown in *figure 5, Plate XVII.*, which represents a vertical section of this syphon), so that one end of it rises nearly perpendicularly somewhat higher than the top of the syphon, for connecting it by means of a hole drilled and tapped into the under side of the main pipe (before it is laid down), through which any condensed matter descends into the syphon, whence it is occasionally removed by means of a portable pump, which screws upon the upright pipe passing through the lid. The top of that pipe is secured by a cap of wrought-iron, which screws upon it, and is only taken off

when it is necessary to ascertain whether the syphon contains water, and, if so, during its removal.

The gun-barrel syphon is generally about eight inches deep and four inches diameter (see vertical section, *Plate XVII.*, *figure 6*). Through the blank flanch at the top is introduced a piece of three-quarter-inch wrought-iron tube, which descends nearly to the bottom, generally called "the suck pipe." On each side of this syphon is a piece of wrought-iron tube, bent as shown in the figure. This syphon is used upon the service pipe to answer the same purpose there as that answered by the larger one upon the street mains.

*Figure 7, Plate XVII.*, is a section of the improperly-so-called tar-well. It is a cylindrical vessel of about ten inches diameter inside, and twelve inches deep when used upon any main of less than ten inches diameter; but when it is used upon larger mains, the diameter of the body of the tar-well must be two or three inches more than the diameter of such mains. This vessel is cast with a socket at one side and a spigot at the other, similar to those of the pipes with which it is connected; therefore, a tar-well with a socket and spigot similar to those of a two-inch pipe is called a two-inch tar-well, one for a three-inch pipe, a three-inch tar-well, and so on.

From the condensation which takes place in the main pipes, it is found necessary to lay the large pipes, and also the small or service pipes with a small



Thos. S. Peckston.

London: Published by E. Hebert, 20<sup>th</sup> Feb<sup>r</sup> 1841



declination, in order that the condensations may, from this inclined position of the pipes, descend to the lower parts of said pipes, where the syphons or tar-wells must be fixed for receiving any condensed matter. Over the syphon, as well as over the tar-well, is generally placed a wooden block bored out at the centre, and fitted with a cast-iron bush, and lid at the top, lying level with the pavement, for the purpose of being able to get at and unscrew the cap of the suck-pipe, and to connect the portable pump thereto.

On referring to the plans of the gas-holders and tanks N and O, Plate VI., it will be observed that the inlet pipes *ee* enter each of these gas-holders from a cylindrical vessel something similar in shape to figure 5, Plate XVII., and the exit pipes from the said gas-holders enter into the same vessels by the pipes *f* and *g*. These vessels will vary in size according to the size of the inlet and outlet pipes. For four-inch pipes, a vessel eighteen inches diameter inside, and about two feet six inches deep, will be amply sufficient. It must be cast with a partition that shall approach to within about two inches of the bottom, and rise about three inches and a half above the top of the flanch, in order that two semi-circular lids may be thereto secured in the usual way, so as to be gas tight. On the outside of this vessel must be cast two sockets, for receiving the spigot ends of the cast-iron pipes which pass through the

wall where brick or stone tanks are used, and into the gas-holder tank, one on each side of the partition already alluded to, and with such an angle between the two as will bring the upright parts to the positions in which it is desired they should stand. One of the semicircular cast-iron lids is to have a socket cast upon it for receiving an upright pipe of the same diameter as the inlet pipe, and the other, in addition to such a socket, is to have a second socket cast upon it for receiving a two-inch cast-iron pipe, which pipe is to be carried up to the surface of the ground, where it will terminate with a flanch about two inches broad. A cast-iron blank-flanch, with a boss on the centre, must be secured to the upper flanch by three half-inch screw bolts, and made gas tight by means of a pasteboard joint. Through the centre of this blank flanch or lid must be drilled and tapped a hole, through which must be screwed a sufficient length of three-quarters-inch wrought-iron pipe, to descend to within about five inches of the bottom of the cylindrical vessel (with the partition therein as already mentioned), and to come through the top of the blank flanch, with its screwed part about three inches, in order that a cap may be screwed thereon. The object of this pipe is to draw off any condensed water by means of a portable pump, from the cylindrical vessel to which the inlet and outlet pipes are jointed, which pipes must be laid with a fall of about three-quarters of an inch to the yard towards that

vessel, to prevent any lodgment of water in them. The use of the partition-plate in the cylinder is to prevent the gas entering into the gas-holder except by the inlet pipe, for it is evident that the suction pipe will always allow full five inches in depth of water at the bottom of the cylinder or receiver (to which depth it must be filled, by pouring water down the three-quarter-inch pipe before the gas-holder is brought into action), consequently the partition-plate will always have a dip of three inches, which will effectually prevent any communication between the inlet and outlet pipes in that vessel. Pieces of the same sized pipe as the inlet and outlet pipes are placed upright in the larger sockets on the lid of the receiver, into which they are secured by well made lead joints. At the upper end of these pipes are jointed the quarter-bends which connect with the pipes leading towards the purifier, and towards the governor or regulator P, Plate VI. It will be best to connect an hydraulic valve with each of the bends just spoken of, before the pipes *e*, *g* and *f* are connected ; when a regulator is used, should that not be the case, and the street main be supplied immediately from the gas-holder N or O, then hydraulic valves should be used only upon the inlet pipes, that is, upon those between the gas-holder and the purifier and slide valves (to work with a screw), on each of the bends connected with the outlet pipes, so that the orifice of supply to the streets may be enlarged to the full bore of the pipe,

or lessened to such size as may be sufficient for the supply. By adopting this plan, the pipes *e e*, *g g*, which run nearly parallel to the coke-store *Q Q*, will lie about eighteen inches below the surface of the ground. A brick wall will require to be built round the valves, so as to leave an opening round them about two feet square, which opening can be covered by a cast-iron plate, or Yorkshire flag, with a hole over the spindle of the valve, so that the valve can be raised or lowered by means of a T-shaped key. Under this arrangement there is no necessity for any syphon well to the gas-holder tank, and the earth round the upright pipes can be replaced to the regular level of the ground, and thus a considerable saving will be effected, particularly where brick or stone tanks are used for the gas-holder to work in, as the syphon well would require to be built, in such cases, very water tight, and well puddled.

## CHAPTER XIII.

On the laying down of Main Pipes in the Streets, &c., the Arrangement of their diameters, and remarks thereon: also on the Service Pipes, Gas-fittings, and Burners.

THE results of a great many years' experience in the casting of pipes for the conveyance of gas now obtained at all the large iron-works throughout the country, renders it almost needless to enter into any long details upon the subject of the weight or form of pipes used by the gas-light manufacturer. Generally speaking, all he has to do is to give his order for the number and kind of pipes, bends, branches, &c., he may require, for all of which the respectable iron-founder is prepared with patterns of such thickness of metal as experience has proved most proper. We shall especially here have occasion to speak about that arrangement of the street mains in which those of the largest diameter are nearest to the manufactory, and the branches from them are proportioned to the demand they will have to supply; but before we do so, we will give a description of the various kinds of cast-iron pipes used, and the mode of connecting them together.

*Plate XVIII., figure 1*, is a longitudinal section of

the socket pipe. These pipes are connected together in the following manner :—the workman having introduced the spigot end of one pipe into the socket of the pipe adjoining, passes gasket or spun-yarn round it till the socket is filled therewith (when well set up by means of a proper caulking-tool and mallet) to within from an inch and a half to three inches of its entire depth, the smaller depth left vacant being sufficient for the lead which forms the joints in all pipes up to four inches diameter, and the larger depth being sufficient for pipes of from fourteen to eighteen inches diameter, the depth for the lead gradually increasing from one inch and a half to three inches, as the diameters of the pipes increase from four to fourteen inches. This being done, he makes a roll of clay, of a sufficient length to go quite round the pipe, and passing it underneath the pipe, he forces the clay close up to the edge of the socket, quite round, and joins it at the top, where he forms an opening or lip for receiving the melted lead which he has ready for use. Things being thus arranged, he takes a sufficient quantity of lead in his ladle, and pours it into the socket through the opening just mentioned, till the socket is entirely full, which is known by the lead rising to the top of the clay. So soon as the lead is set, the clay is removed, and he proceeds to make the next joint in a similar manner. After making two or three joints, and allowing the lead to become quite cold, the lead is

driven up (or, as it is generally termed, set up) by means of a caulking-tool and mallet, and thus joints perfectly gas-tight are formed. The centres of the adjoining pipes must be brought into a line by means of the gasket used before the melted lead is introduced; for unless this precaution is taken, the outside of the spigot end of the pipe will not be equidistant from the internal surface of the socket, in which case the body of lead introduced for making the joint will not be of equal thickness throughout, consequently a joint so made will be more likely to become leaky than those made in a workmanlike manner, as we have just described.

Roman-cement has, in some cases, been used for making good the joints of socket pipes, and, as far as tried, has been found to answer that purpose. In making the joints according to this method, it is only required to bring the centres of the adjoining pipes into a line, and then to introduce the cement, just mixed, between the socket and spigot by means of a blunt instrument, forcing it up so as entirely to fill the cavity. Roman-cement increases in bulk by drying; consequently it forces itself so compactly between the outside of the spigot and the inside of the socket of the respective pipes, as effectually to form a joint. It has been ascertained by experiment, that cast-iron pipes thus connected together are less liable to fracture at the joint than in any other part.

To prevent the necessity of using any material (beyond white or red-lead, which may be applied by means of a brush) for filling the cavity between the outer surface of the spigot and the inner surface of the adjoining socket, when socket pipes are used, a description of pipe has of late years been manufactured, and which has been very generally used, differing somewhat from the socket pipes we have been speaking of. They are cast with a collar round the socket of from three to four inches broad, and to that depth the pipe is about twice as thick as it is in any other part ; their sockets are also cast stronger than those for pipes where lead joints are used. Being thus prepared, the outer surface of the spigot end is turned so as to be very slightly conical, and the interior of the socket is bored by means of an instrument so gauged as that when the spigot end of a second pipe of the same bore is introduced into it, the two pipes fit closely, similar to the ground stopper of a decanter. In laying such pipes down in the streets, the workmen give the spigot end a thin coat of red or white-lead, introduce it into the adjoining socket, and drive it home by means of a tolerably heavy wooden mallet. Where there is a considerable distance of pipe to be laid in a straight line, turned and bored pipes are well adapted for the purpose ; and although they are generally charged by the iron-founder at a somewhat higher price than the ordinary socket pipes,

they are much cheaper in the end from the saving of gasket, lead, labour, and time in laying; for an expert pipe-layer would lay ten turned and bored pipes (supposing the ground to be got out ready) in less time than it would take him to make a couple of lead joints.

*Figure 2, Plate XVIII.*, is a view of socket pipes when joined together.

*Figure 3, Plate XVIII.*, is a longitudinal section of flanch pipes, in which the manner of connecting them together is shown. The joint is made by first introducing a small ring of the diameter of the pipe made of iron, covered with yarn or any pliable material which is between the two flanches, which flanches are kept together by means of screw-bolts and nuts, and gas tight by means of iron-cement well caulked up.

To make iron-cement for this purpose, or for making any other flanch joints as in tanks, in connecting the mouth-pieces to the retorts, the dip pipes to the hydraulic main, &c., take iron turnings or borings and pound them in a mortar till they are fine enough to pass through a fine sieve; then, with one pound of these borings so prepared, mix two ounces of sal-ammoniac in powder, and one ounce of flowers of sulphur, by rubbing them well together in a mortar, and afterwards keep the mixture dry till it may be wanted for use. When it is so, for every part thereof by measure, take twenty parts of

iron-borings, prepared as above-mentioned, and mix them well together in a mortar or other iron vessel. The compound is to be brought to a proper consistence by pouring water gently over it as it is mixing; and when used, it must be applied between the flanches by means of a blunted caulking-iron, where it is to be well set up; when so, the nuts of the connecting bolts must be screwed up very tight and the loose cement scraped off, after which the face of the joint must be smoothed by a small trowel so as to give the joint a workmanlike appearance. The affinities between the ingredients of which the above cement is composed, are such as cause a degree of action and re-action amongst them, and also between them and the surfaces of the iron flanches; ultimately causing the cement and the surface of the flanches to become a species of pyrites, cohering together with considerable strength and compactness.

*Figure 4, Plate XVIII.*, is a view of flanch pipes joined together.

*Figure 5, Plate XVIII.*, represents what is called "a branch pipe." It has a socket at one end and a spigot at the other, between which a pipe branches off with a curve; and according to the diameter of the curved part, it is called a two, three, or four-inch, &c. branch pipe. Its use is to lead off from the larger mains into streets at right angles to them. The pipe itself being of like diameter

with the larger main, and the branch answering to the socket of the pipe which may be continued from it. It is more convenient to have the branch cast with a socket upon it for connecting the pipe which joins it, as in that case the workman has more room for making his joint, and his pipes follow in regular succession for his work. When a pipe of this description has a branch from each side, it is called "a double branch pipe."

*Figure 6, Plate XVIII.*, is a cast-iron pipe used for the same purpose as the former; but instead of branching out with a curve, the pipe leads off at right angles. Pipes of this description are termed "outlet pipes." It is better that the outlet should be cast with a socket upon it than with a spigot, for the same reason as that given when speaking of branch pipes.

*Figure 7, Plate XVIII.*, represents what is called "a diminishing pipe." It is used when it is required to decrease the diameter of the range of main pipes, the socket at one end answering to the spigot of the larger main, and that at the other receiving the spigot end of the smaller main.

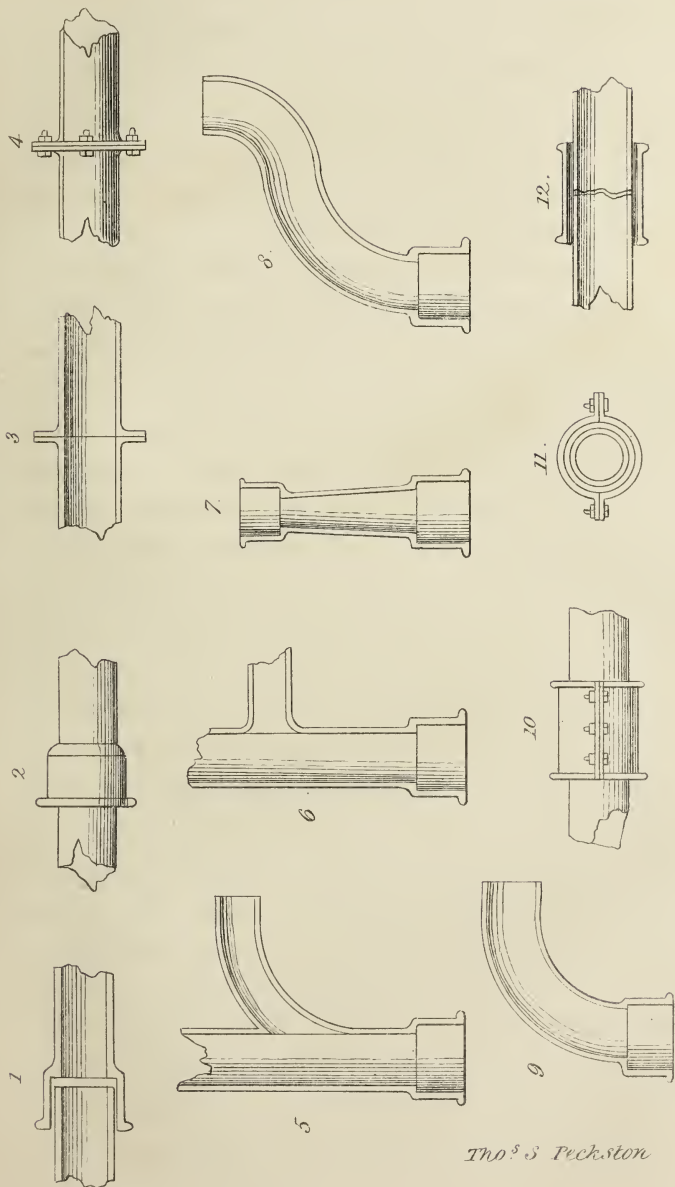
*Figure 8, Plate XVIII.* When a pipe is cast so as to form a double bend, or somewhat to resemble the Roman letter S, it is called "an ess pipe."

*Figure 9, Plate XVIII.*, is "a bend pipe." It is called a quarter-bend, eighth, or sixteenth-bend, as it forms such part of the periphery of a circle,

and according to the radius with which it may be struck: the diameter of the pipe in inches is always prefixed for the sake of distinction to the foregoing denominations, as one, two, three-inch quarter-bend, &c. The uses of the ess pipe and bend are too obvious to require any explanation.

It is sometimes necessary to make a junction between the spigot ends of two socket pipes. This may be effected by means of "the thimble-joint," as exhibited in figures 10, 11, and 12, Plate XVIII.; or by "a double socket," which is a casting of from six to eight or ten inches long, and in diameter about one inch more than the outer diameter of the pipes to be connected: it is brought over the pipes, the pipes to be joined in a way similar to what is shown in the thimble-joint (figure 12, Plate XVIII.), and jointed with gasket and lead in the ordinary way, or by an iron-cement joint. The double socket should be cast with a bead round each end outside for the purpose of affording strength, and to prevent its being split by caulking up the joint.

When it is requisite to carry a smaller main pipe from a larger one already laid down, a part of the main pipe is sometimes cut out and a branch pipe introduced into the vacant interval. This object is more easily effected by cutting a hole of the diameter required through the side of the main, and by means of two castings somewhat like the thimble-joint, one of which must be cast with a socket upon it to



Thos<sup>s</sup> Peckston

London Pub<sup>d</sup> by E. Hebert, 20<sup>th</sup> Feb<sup>y</sup> 1841



receive the spigot end of the pipe which is wanted to be laid down, so that the pipe may be jointed thereto in the usual way.

It will appear reasonable to most persons that the main pipes for conveying gas may, with safety, be cast much lighter than pipes of the like diameter for conveying water; for the internal pressure in gas-pipes rarely exceeds an inch and a half head of water. From the depth at which gas-pipes are generally laid, there can be no apprehension of accident from external pressure; and their situation, when laid down, precludes almost all possibility of their being much injured by oxydation outside.

In the arrangement of street mains, where new works are to be built, the first thing to be considered for determining their size is to endeavour to ascertain the quantity of gas which may be called for in an hour for lighting public and private lamps, fully equivalent to the conveyance of which must be the diameter of the principal main pipe from the manufactory to the point where the first branch pipe is placed; and, as the branches are inserted, we must diminish the capacity of the leading main to nearly the amount of their respective areas, so that, after the insertion of each of the branches, the leading main may have its diameter (consequently its capacity) lessened to nearly the extent of the branch pipes proceeding from it: consequently, though the first portion of the leading

main may be fourteen or sixteen inches in diameter or more, it may terminate in a pipe of two inches or even one and a half inch diameter.

To ascertain the diameter of pipes capable of supplying a certain quantity of gas in a certain time, it is stated by persons conversant with the subject, that, as precisely the same laws exist with respect to the rate of discharge through orifices or tubes in or connected with a reservoir, of elastic as of non-elastic fluids at any pressure, so the initial velocity (or primary pressure) of the gas in the main pipe varies directly as the square root of the column of water pressing on the gas-holder, and inversely as the square root of the gravity of the gas, and also the volume of gas discharged from the end of the pipe varies directly as the square of its diameter, and inversely as the square root of its length. All these theoretical deductions are sufficiently justified by practice, with the one exception, however, of the inverse ratio of the square root of length, which regards pipes of *nearly equal length only*, with heavy fluids, as water, according to Bossut, who states that this rule, even in this case, is merely an approximation, not deduced from principle, but from experiment (See Dr. Gregory's *Mathematics for Practical Men*, 2nd Ed.); consequently with respect to the influence which the length of the pipe exerts upon the volume of gas discharged at its end in comparison with that discharged at the end of a like pipe

of very different length, our safest plan is to found and build up our knowledge thereof on the results of experiment solely, for thereby alone can the amount of friction, and consequent retardation, of the gas in straight pipes be nearly found. In the practice of gas-lighting, by far the greatest attention is paid to the diameters of the mains being adequate to the supply thence required, as in this point an error of calculation is highly injurious; the retardation of the gas by friction along the sides of the pipes is very seldom taken into consideration, it being found that the pressure of the gas at any one point in the same level is the same when no lights are burning, and no leaks exist, and consequently the difference of pressure felt at these scattered spots, when the burners are lighted in the district, arises merely from the decrease of volume produced at every burner by the portion of gas drawn off from the length of main between the burner and the gas-holder, or by a loss of velocity, and consequently of volume discharged caused by the gas having had to pass through bent and angular branch and service pipes. That the retardation, and consequent decrease of volume in the gas discharged, arising from its friction, along the straight side of a tube is inconsiderable, the foregoing sentence in a wise explains; of this we have also ample testimony in filling the street mains with gas on the first night of lighting up a town, when the gas traverses the said mains, expelling the air with

wonderful rapidity. The great levity of gas, however, counteracts many of the effects we might suppose would be produced, and renders calculation very uncertain on this subject, which is still well worthy the investigation of the experimental analyst.

Dr. Ure, in his Dictionary of Manufactures and Mines, has given a formula founded on the deduction by experiment, that through a pipe 250 feet long, one inch in diameter, 200 cubic feet of gas are transmitted in one hour. He, calling the diameter  $D$ , the volume of gas transmitted in one hour  $K$ , and

the length of pipe  $L$ , makes  $D = \frac{\sqrt{K\sqrt{L}}}{455,000}$ , and sub-

joins a table of proportions hence said to be deduced. A learned friend has favoured me with a formula founded on Dr. Ure's hypothesis, widely different

from the former,  $D = \left( \frac{K\sqrt{L}}{12^2 \cdot 10^2 \cdot 2\sqrt{250}} \right)^{\frac{1}{2}}$ : this gives

nearly the same results as those in the Dr.'s table. The results of that table are altogether erroneous, and more especially so in the case of pipes of large diameter, the number of feet discharged being in every instance strikingly too small for practice; which error principally arises from the wrongly surmised influence of the length of the pipes upon the velocity of the gas pervading them. For instance, a pipe of 16.65 inches in diameter is there found requisite, being 2,000 feet in length, for the hourly

transmission at, I suppose, the ordinary one-inch pressure of 8000 cubic feet of gas, whereas a pipe of the foregoing diameter is found in practice capable of transmitting at one-inch pressure the very much greater number of 110,000 cubic feet. Whence we may reasonably conclude the practical inutility of this rule, involving as it does results from friction in the motion of gas actually impossible.

From experiments carefully made many years ago, and confirmed by many subsequent ones, we are aware that when the gas-holder is worked with a pressure of one inch, a tube one quarter of an inch in diameter will deliver 20 cubic feet of gas in one hour, a tube half an inch diameter will deliver 90, and a tube one inch in diameter will deliver 500 cubic feet of gas in one hour. Supposing, therefore, that the inverse ratios of the length of the pipes have very little if anything to do with the diameters of the supply pipes, and that in practice we may take the squares of the diameters for finding the sizes of main pipes without any reference to their lengths, having from *actual* experiment ascertained what quantity of gas a pipe of one-inch bore will discharge in one hour, when the gas-holder is worked at a certain pressure, we may find the diameter of any other pipe capable of delivering some other specific volume of gas in a like time, under a similar or any other pressure.

If we should be desirous of knowing what the di-

iameter of the pipe ought to be which would supply 18,000 cubic feet of gas in an hour, when the gas-holder is worked at one-inch pressure, we should proceed thus:—

As the quantity of gas passing through a pipe of one-inch diameter, the gas-holder working at one-inch pressure,

Is to the quantity of gas required to be conveyed through another pipe, the gas-holder working at a like pressure,

So is the square of the diameter of the pipe whose volume of discharge is known.

To the square of the diameter of the pipe for conveying the quantity of gas required,

C. feet.	Cubic feet.	In.
----------	-------------	-----

thus, as  $500 : 18,000 :: 1^2 : \sqrt{36} = 6$  inches.

In practice, however, in order to make ample allowance for friction in the pipes, and other contingencies, we may name 400 cubic feet as the quantity which an inch pipe will deliver in an hour, when the gas-holder is worked at one-inch pressure: proceeding under this *datum* to find the bore of a pipe sufficiently large for supplying 18,000 cubic feet of gas in an hour,

C. feet.	Cubic feet.	In.
----------	-------------	-----

we must say as  $400 : 18,000 :: 1^2 : \sqrt{45} = 6, 7$  inches the diameter of the required pipe. This rule is quite enough to attend to practically; but, in cases where a greater nicety is required, and where it is thought desirable to take into account the column

by which the gas is pressed, or the specific gravity of the gas, what we said at page 344 will enable the reader to follow up the matter so as to produce the nicest theoretical results.

After what has been already advanced, the reader will easily be able to calculate the size of main pipes required for a gas manufactory where the quantity of gas to be daily used is known. We shall therefore proceed to make a few observations relative to the laying down of main pipes, to which the strictest attention is indispensable. In a former chapter it was observed that considerable condensation takes place within the main pipes; if, therefore, they be laid perfectly horizontal, they will with difficulty be kept unclogged by the condensed fluid. To facilitate the getting rid of condensed matter, the pipes should be laid with a fall of about an inch in twelve yards run, or a fall of about one foot in 150 yards: if then the first 150 yards of main pipe be laid with this fall, the next 150 yards are to have the same rise. Under this arrangement, the water of condensation will fall to the lowest part, and a receiver (a "syphon" or "tar-well") being there fixed, will receive it; and thus the pipes can always be kept clear of such a quantity of water as might impede the passage of the gas, by examining the receiver occasionally, and, when needful, drawing off the water therein accumulated, the quantity of which may be ascertained by unscrewing the cap on the suck-pipe

of the receiver, and dropping a rod through that pipe so as to touch the bottom, which on being withdrawn will show the height at which the water stands therein. Were this rule at all times attended to, the introduction of many syphons and tar-wells (receivers) on the range of main pipes might often be dispensed with. In some cases the very uneven surface of the street, &c., under which the pipes are laid will not admit of this rule being carried fully into effect; but it may be observed, that a want of care in this matter, on the part of the pipe-layer, is often strikingly evident.

When the levity of the gas is considered, it is by no means surprising we should notice with what celerity it finds its way to the higher part of the mains. So striking is the effect, that it must have attracted the notice of almost every observer; for when there has been an abundant supply of gas in some situations in the metropolis, which are very remote from the manufactory, persons residing in other situations much nearer to the works have been able to obtain but a very feeble light. If we were asked from whence does this variability arise, we should answer that we had no doubt but the more distant points were situated on much higher ground than the nearer, and that for that reason the gas would have a natural tendency to press towards such points. This levity of the gas has been particularly observed in some of the theatres; for it has often

been remarked there, when the lights to the lower tier of boxes have burnt very feebly, that those near the top of the house burnt with much vigour. Considering then the tendency which gas has to ascend, it is evident that when towns are to be lighted with gas which vary considerably in their level, it will always be desirable to lay the pipes of the largest diameter in the lowest parts, gradually decreasing their size as they proceed towards those more elevated, if it be intended that the gas should issue from burners in both situations with a like impetus.

We need not add more relative to the main pipes, and therefore turn next to the service pipes for conveying the gas from the street mains into the houses or other places where the gas is required. These are made of welded-iron tubing, generally made in lengths of nine feet with a female-screw socket screwed upon one end, and having at the other end a male screw with a similar thread in order that they may be easily connected together. Bends, T-pieces, &c., are made of the same material, the former for insertion into a hole tapped and drilled into the main pipe, or for making any bend in the service pipe, and the latter for carrying off branches from the service pipe to the right or left, as may be needful. There are also used upon the service pipe when circumstances render it necessary, short lengths of tubing furnished with a double socket called connecting pieces; that is to say, pieces

of tubing of from six to eighteen inches in length with a male screw at one end and a female screw at the other, wrought-iron crosses for branching off from the principal service pipe in two directions and gun-barrel syphons. The service pipes, bends connecting, and T-pieces are of different diameters, from half an inch to an inch and half diameter. Pipes, bends, &c., of larger bore are generally made of cast-iron. The service pipe requires to be laid sloping, so as to allow the condensations to drain off either into the main pipe or the gun-barrel syphon. The service pipe is generally carried by the gas company's workmen from the street main into the interior of the house where the supply of gas is wanted, and the end secured by means of an iron cap screwed thereon to prevent any escape of gas till the gas-fitter has prepared the inside work.

The best kind of tubing for internal work is what is now well known to all gas companies and gas-fitters as "drawn tin tube," which can be connected together by means of union joints or by soldering with the blow-pipe. It is very stiff and yet can be bent where necessary, so as to preclude the use of elbows, which frequently could not be dispensed with when iron or brazed copper tube were used for the internal work. It is much more durable than either iron or copper pipe not being acted upon by the gas which passes through it; and where seen, it is not at all unseemly.

Various descriptions of burners have from time to time been used, but all of them which are now in use are in appearance nearly similar to those shown in Plate XIX., which we shall now refer to. *Figure 1* in that plate exhibits a vertical section of the argand shank, or, as it is sometimes called, the spout-burner. This burner is used when the fittings are brought towards it in a horizontal direction. It will be observed that it is constructed of two concentric circles of metal joined to a small tube at one side near the bottom, for screwing it to the bracket or other fitting. These two circles are connected together at the top by the circular steel plate, as shown at figure 2, which is drilled with the number of holes wanted. *Figure 3* is a vertical section of the argand crutch-burner. The body of this burner is similar in all respects to that of the shank-burner; but as it is intended to be used at the top of a pillar, the tubing is joined to the bottom in a crutch-formed shape, from whence it derives its name. The reader cannot fail, from a mere inspection of the figure, to observe the proportion of parts maintained in its construction; but to give him further explanation relative to the subject, we subjoin the dimensions of the particular parts of the body of the argand burners as shown in Plate XIX.

Dimensions of the 12-hole argand burner :—

Outer diameter of the top  $\frac{1\frac{3}{6}}{16}$  of an inch.

Inner diameter of the top  $\frac{1}{3}\frac{5}{2}$  of an inch.

Diameter of the circle of holes  $\frac{5}{8}$  „

Diameter of each hole  $\frac{1}{3}\frac{1}{2}$  „

The holes drilled in the top of this burner are  $\frac{5}{3}\frac{1}{2}$  of an inch from centre to centre. The diameter of the bottom of this burner is  $\frac{7}{8}$  of an inch. The bottom is bell-mouthed inside as shown in the figure. This burner is 1 inch and  $\frac{7}{8}$  in height, and the distance from the top to the shoulder for supporting the glass-holder is 1 inch.

Dimensions of the 15-hole argand burner:—

Outer diameter of the top  $1\frac{1}{16}$  of an inch.

Inner diameter of the top  $\frac{1}{3}\frac{9}{2}$  „

Diameter of the circle of holes  $\frac{3}{4}$  „

Diameter of each hole,  $\frac{1}{3}\frac{1}{2}$  „

The holes drilled in the top of this burner are  $\frac{3}{1}\frac{3}{6}$  of an inch from centre to centre. The bottom of this burner is  $1\frac{1}{8}$  inch in diameter. The bottom is bell-mouthed inside as shown in the figure. Height of this burner 2 inches. Distance from the top to the shoulder for supporting the gas-holder  $1\frac{1}{4}$  inch.

Before speaking of other burners, we must not omit to mention that in order to secure a more perfect combustion of the gas, the supply of air through the centre and between the exterior of the argand burner and the glass chimney, Messrs. E. and W. Dixon, Walsall, attached a conical piece to the outside of the burners they manufactured which rose just to the top of the burner, leaving a very

narrow passage for the air; and, more recently, Messrs. Platow, Morritz, and Co., of 40, Hatton Garden, have manufactured an improved patent argand gas-lamp, which is designated “the double cone burner.” The air-passage communicating with the interior of the flame is contracted by inserting therein a thin inverted metal frustum of a cone, and the exterior of the flame is protected from an excessive supply of air by a metal cone attached to the glass-holder. This arrangement causes the light produced to burn steadily and renders it very soft and agreeable. A saving of gas is effected by its use amounting to about ten per cent.; whilst the heat generated thereby is proportionably less than when the common argand burners are used.

*Plate XIX., figure 4*, is a plan of the top of a burner sometimes used as a street-light, and *figure 5* is a vertical section thereof; the dimensions of which are as under:—

Diameter of the top,  $\frac{5}{8}$  of an inch; it is drilled with three holes each  $\frac{1}{3\frac{1}{2}}$  of an inch in diameter and  $\frac{3}{8}$  of an inch asunder. It is  $1\frac{3}{8}$  inch in length.

*Figure 6, Plate XIX.*, is a vertical section of the bat's-wing burner. This burner is made of steel. In it is drilled a hole of about  $\frac{1}{16}$  of an inch in diameter, to within a small fraction of an inch of the top, from whence is a slit across the burner, falling about half-way of its length. When the gas is turned to the burner and ignited, it exhibits

itself in a flame somewhat similar to the shape shown in the profile, figure 7. From this shape of the flame it has derived its distinguishing appellation. There is another burner sometimes called a "swallow's-tail" and sometimes "a fish-tail" burner, very similar in appearance, as to the flame it gives out, with the bat's-wing burner. The exterior appearance of the burner is similar to that of the bat's-wing:—instead of the slit, as in that burner, the fish-tail has two holes drilled obliquely to make the flame cross. It is a very useful burner, and consumes not much more than half the quantity of gas that is consumed by the small sized bat's-wing burner. The combustion thereby is generally very complete.

*Figure 8, Plate XIX.*, is the profile of a burner from whence issues a single jet of flame. *Figure 9*, profile of a burner yielding three jets of flame. *Figure 10* is the section of a fancy burner producing eight jets. *Figure 11*, section of the union-joint and the tube for connecting it. *Figures 12, 13, and 14* are profiles thereof. *Figure 12* shows a part of the drawn tin tube, at the end of which, intended to be introduced into the socket, is sometimes soldered or screwed a brass collar. *Figure 13* is the socket, tapped for receiving the adjoining length of tubing, upon which is soldered a screw fitting into it. This part is shown by *figure 14*. When the joint is to be made, the workman introduces the

tubing figure 12 through the socket figure 13, so that the collar may rest against the bottom of the socket. Upon this is placed a leather collar similar to figure 15; and upon this again is screwed the tubing shown at figure 14. It is evident that when this is screwed up, the joint will be perfectly gas-tight.

By examining the bat's-wing burners, shown at Plate XIX., figures 6 and 7, it will be seen that they are screwed round the bottom outside, for the purpose of being connected to a socket having a corresponding female screw. When the tubing to which they are to be attached rises vertically, the upright socket, or cone, *figure 16*, is screwed upon the top of that tube. This socket is tapped at each end, the larger screw being that which is joined to the tubing when connected; the smaller one receives the burner tip, whether "bat's-wing" or "fish-tail." But when the tube of supply lies in an horizontal position, the elbow socket, *figure 17*, is substituted for the former. This socket is also fitted with two screws, similar to those in figure 16.

*Figure 18* exhibits a brass cross, used in forming connexions. It is introduced when the fittings branch off in three directions. To form the junctions therewith four union joints would be required. Each point of this cross is furnished with a screw similar to that shown at figure 14 of this plate, and intended to answer a like purpose.

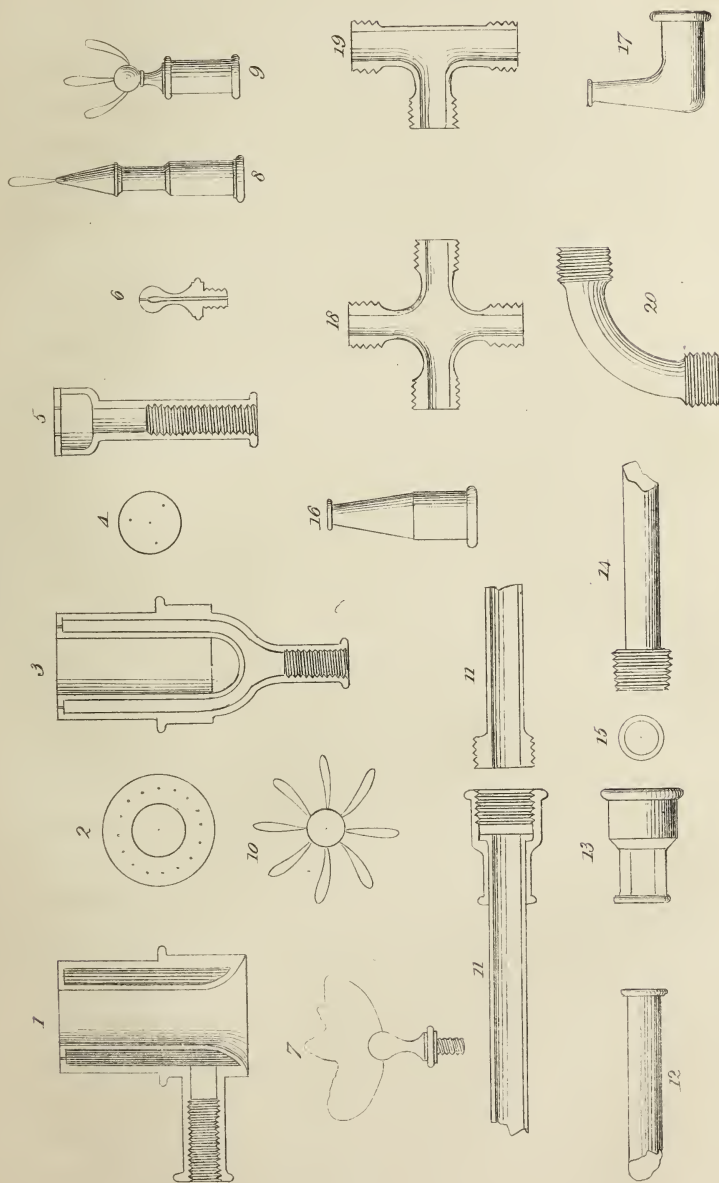
*Figure 19* shows a brass T-piece. It is used when the fittings branch off in two directions. There are provisions made in this for joining with the tubing, similar to those described when speaking of the cross, and the joint is made good in the like manner.

*Figure 20.* A brass bend, sometimes used upon the fittings; each end of it is finished, so as to connect with a union joint: it is not, however, used where the fittings are of "drawn tin tubing," which admits of being bent where needful.

Many devices might be introduced here of pillars, brackets, pendants, chandeliers, candelabras, &c., but they would only increase the bulk of the work without adding to its utility. Persons desirous of obtaining pillars, pendants, chandeliers, &c., will find a great variety of patterns to choose from at the establishments of all the gas-fitting manufacturers in London and in the country, as pattern-books and patterns in great variety are generally to be seen on application to them.

It is of the utmost importance that the gas-fittings in a shop, house, &c., should be judiciously arranged, so that all the burners brought from one service pipe may burn with an equal intensity of flame; and it is of no less importance, that the pipes and other fittings should be done in the most workmanlike manner, so that there shall not be the smallest leak in any part of the work. The doing of all this

Plate 19.



Thos. S. Peckston.

London: Published by E. Hebert, 20<sup>th</sup> Feb. 1844



properly will be best effected by employing a respectable and experienced gas-fitter, which can always be done in towns where gas-works have been for some years established ; but in such towns as may hereafter be lighted, we recommend, that the tradesmen who undertake to do the fittings should each employ one experienced gas-fitter, as the most certain means of ensuring the work being properly done. For want of such precaution, mistakes have arisen injurious to the consumer and detrimental to the interests of the gas manufacturer ; the former being annoyed by escapes of gas, or by some of his lights burning indifferently, speaks of the circumstance to his neighbours, and thus prevents them from using gas, so that thereby the manufacturer of that article loses the profits upon a portion of gas which would otherwise be supplied.

## CHAPTER XIV.

## On the Gas-Meter.

AMONGST the improvements which have been made in the apparatus connected with the manufacture and distribution of gas, the gas-meter holds an important place. When used between the purifier and gas-holders, it measures and registers the quantity of gas ready for use, which may be generated when between the gas-holder and street mains; the quantity of gas supplied from the manufactory, for lighting the public lamps and to meet the demand by the private consumers; and, when constructed on a smaller scale and fixed in the houses of the private consumers respectively, it points out the number of cubic feet of gas that each may have burnt in any specific time.

Before going into detail relative to the use of this simple piece of mechanism, it may not be uninteresting to the reader should the history of its origin be given, and the various changes it has undergone, till brought to its present form. Formerly, the general mode of charging persons for gas, by the different gas companies, was a certain sum per annum for burners of given dimensions,

burning from sun-set till nine, ten, or eleven o'clock, &c. But this mode neither answered the end of the supplier nor that of the consumer of gas. The improvident consumer was seldom careful to adhere to the time of burning, or to the height of flame, stipulated; whilst he who was more scrupulous in those points had no pecuniary advantage arising from his carefulness; consequently, an instrument that would measure correctly the quantity of gas used by each individual consumer became a thing of importance; for, by such a one, the improvident would have to pay for his improvidence, whilst he who burnt his gas carefully would be benefited thereby in a pecuniary point of view, and the manufacturer would be certain of being paid in each case the full value of the gas supplied.

The idea of selling gas by measure, instead of the very unsatisfactory method of disposing of it by the time of burning and size of burner, seems to have originated with the Chartered (or Westminster) Gas-light Company, in the year 1815; for, in the latter end of that year, or very early in the ensuing one, Mr. Samuel Clegg, who was at that time the Company's engineer, constructed a gas-meter of the following description:—To a wooden frame were attached two small cylindrical vessels, into each of which worked a gas-holder, containing, we will say, for the sake of speaking of a specific quantity, one cubic foot. The pipes supplying these gas-holders

were intended to be connected to the service pipe leading into the house where the meter was to be used. By means of a beam (supported at its middle, and from the ends of which the gas-holders were suspended over and into their respective vessels) and a mercurial valve, the action of this reciprocating gas-meter was as follows:—the gas being turned on from the street, filled one of these gas-holders; and when it became so, the beam we have spoken of, acting upon a smaller beam attached to the valve, shut off further supply to the one that was full, and opened a communication to the empty gas-holder, as well as from the full gas-holder to the pipe for supplying the burners. By the time the second gas-holder was full, the gas in the first was consumed, and therefore it was down in its tank, and the full one performed the action of change, as the former had done when it was full of gas. Thus they alternately were filled and emptied, and the number of times they did so was pointed out by an index, which consequently showed the number of cubic feet of gas which had passed through the meter. Had this answered the end in view, it would doubtless have been adopted: the process appeared in theory likely to have done so; but, on considering the nature of the valves and the nicety of workmanship necessary, it is not surprising that it failed in practice. Very considerable expenses were incurred in endeavouring to bring it to

perfection, and much time was spent upon it; but, ultimately, it was altogether abandoned.

Mr. Clegg next attempted to construct a gas-meter having a rotary motion, instead of a vertical one. It consisted of a cylinder divided into several chambers, revolving upon a hollow axis enclosed in another cylinder, which served as a case. For this meter he obtained a patent, the specification with elucidatory engravings of which was given in the thirtieth volume of "The Repertory of Arts" (Nos. 176 and 177, for January and February, 1817), to which the reader who may feel curious as to the matter is referred for its full description. It is probable he will find some difficulty in understanding its action; for, perhaps, for an object which was very soon afterwards accomplished by a method exceedingly simple and beautifully mechanical, nothing of a more complicated nature could have been devised than the rotary gas-meter, as described in Mr. Clegg's specification. The various ramifications of scrolls and the friction arising from the axis of his meter, that working in stuffing-boxes, were both highly objectionable; and, when we consider the light pressure with which it was to work, we ought to be surprised to find, under such circumstances, it ever made one revolution. These were not the only objections against it; it was too large to be introduced into the shops of tradesmen in general, who seldom have much room to spare; and, although it

was put up in some places where many lights were used, its performance was not such as could be depended upon, and it was consequently removed.

When Mr. Clegg retired from the situation of engineer to the Chartered Gas-light and Coke Company (on the 1st of April, 1817), the most improved of his meters were from necessity used with stuffing-boxes ; and, although he had done away with several of the scrolls, shown in the drawing attached to his specification, he had still two scrolls left in each chamber, or division. And so far was he from appearing to contemplate any other mode of introducing the gas into the meter than that by a hollow revolving shaft, that he had all his meters so made up to the very time of his leaving the Chartered Gas Company. On the 4th of April, 1817, Mr. John Malam, civil engineer, then in the employment of the Chartered Gas Company, submitted a drawing of a meter he had invented (similar to that as shown at figures 3 and 4, Plate XX.) to the committee of management of the gas-works situated in Great Peter-street, Westminster ; and, on the 7th of that month, he exhibited to that committee a meter such as the drawings just mentioned describe, and put it into action. Previous to the 13th of the same month, it would appear Mr. Clegg had heard that Mr. Malam was making gas-meters, for on that day he wrote to Mr. Malam to guard him against infringing upon his patent ; but, from the tenor of

Mr. Clegg's letter, it appears he had then no distinct idea as to what was Mr. Malam's plan ; for, he observes, the shutting off the gas may be effected in various ways, that is to say, "by valves, or sealing the pipes with water." If the reader examines the figures representing Mr. Malam's gas-meters, he will find there is not a valve in either, and also that there is not any pipe to be sealed with water.

Under such circumstances it cannot but be astonishing to learn that, when Mr. Malam presented his gas-meter to the Society of Arts, in 1819, Mr. Clegg came forward to try to make it appear, in the first place, that Mr. Malam's improved gas-meter was an infringement upon his patent, consequently that the society could not award him anything for his invention or improvement; and secondly, to dispute about the priority of the invention, notwithstanding the gas-meter for which Mr. Clegg took out his patent, and the improved gas-meter which Mr. Malam brought before the Society of Arts, had nothing in common beyond the outer case in which each was enclosed, and that each had a rotary motion. It would not become us to enter into detail relative to the proceedings which took place before the Society of Arts on this occasion ; we may however mention that, after a committee there composed of some of the then most eminent chemists and engineers in this or in any other country, had for eight hours patiently investigated the business,

they formed a resolution stating *Mr. Malam's gas-meter new, ingenious, superior to other gas-meters, and likely to be of great benefit to the public*, awarding him the society's gold medal for his invention. But, in consequence of some opposition made to the resolution when it was brought before the society, the matter was re-committed and underwent another eight hours' ordeal, from whence it was sent again with the same resolution and the same reward; and on the 28th April, 1819, the society, as a body, voted Mr. Malam their gold Isis medal for his invention.

What we have now stated relative to the rendering the gas-meter really useful, we stated in the former editions of this work, and probably should not have thought of repeating it here, had we not in several works in which the gas-meter has been spoken of, seen the merit of the invention invariably attributed to Mr. Clegg, and the improvements solely to Mr. Crosley: and in no one case have we noticed Mr. Malam as in any way connected with those improvements, though they were the first step towards causing the meter to be what it is. We have been constantly connected with gas-works ever since the period that Mr. Clegg conceived it practicable to produce a reciprocating gas-meter up to the present day, and have been constantly and carefully on the watch to notice improvements as they rose, and are quite prepared not only to say, but to

prove also, by drawings in our possession made in 1816 (before Mr. Malam was connected with any gas company), that he had formed an idea relative to employing the Archimedes screw as a gas-measurer (precisely similar to what is used now); in the beginning of which year he showed us a small one he had made on that plan, having the L-shaped pipe of supply, as shown at D, and receiving chamber C C (figure 4, Plate XX.). As to our holding up Mr. Malam as the inventor of the gas-meter in preference to Mr. Clegg, we do so under the most perfect conviction that we are correct: we have no hesitation in admitting that Mr. Clegg was the first person who patented a machine with a rotary motion intended to measure gas; but, at the same time, we as strenuously assert that no useful instrument for that purpose was made known till April, 1817, when Mr. Malam exhibited one in action at the Westminster Gas Works. We have dwelt rather longer upon this matter than we had intended, in justice to Mr. Malam, and in defence of what we had heretofore stated, thinking that, as the gold Isis medal of the Society of Arts was all he received for his invention, it would have been but fair that, in connexion with the gas-meter, he should have been allowed credit for what he did, instead of every effort having been made to put his name aside, to make room for that of another person. Some one may say Mr. Malam only invented the L pipe

and receiving chamber ; be it so : if that be admitted, the rest follows, for the former completely changed the mode of entrance of the gas into the meter, and removed the great obstacle to the action of such an instrument.

We shall not take up more of the reader's time on this point, but proceed to describe the meter first submitted by Mr. Malam to the Committee of Management of the Gas Works at Peter-street, Westminster.

*Plate XX., figure 4*, is a section through the axes, and *figure 3* a section across the axis. *A A A A*, *figure 4*, is the outer case of this meter, within which the interior cylinder *B B B B*, with the chamber *C C* attached thereto, revolves upon the pivots *a b*, the former pivot (*a*) being attached to the L-shaped pipe *D*, which brings the gas into the chamber *C C*, from whence it is conveyed by the openings *a, b, c, d*, *figure 3*, into the inner cylinder *A B C D*, in rotation, as each of the said openings rises above the level of the water expressed by the dotted line in *figure 3*, and that marked *c*, *figure 4*.

On one side of the outer case is attached a vessel of the breadth of the meter, which rises nearly from the bottom to the height of the water-line in the interior. This vessel is for the purpose of introducing the necessary quantity of water into the meter, there being an opening through the outer case within it, the proper height of the water will

thus be known; for so soon as the water rises above the height with which the meter is intended to work, it will run over the top of this vessel. The opening at the top of this vessel is secured by a small brass plug, which screws into it. The vessel is kept closed when the meter is in action. Whenever it may be desirable to empty the water out of the meter, the introduction of a small syphon through the opening to the bottom of the vessel will accomplish it. The situation of this vessel is shown upon figure 1, Plate XX., where the plug we have been speaking of is marked *g*.

In front of this meter is a small vessel of semicircular shape, rising rather more above the centre of the meter than the water in the interior. It is filled with water to form a joint, and through it is brought the pivot *b* (figure 4), on which, as an axis, is fixed a small pinion or crank acting upon the necessary wheel-work, to point out the number of revolutions made by the meter, or to express by pointers, on a plate for the purpose, the number of cubic feet of gas that has passed through it. This meter being unincumbered by stuffing-boxes, and revolving upon small pivots, is very little impeded by friction, and the water rising above the centre effectually precludes the possibility of a loss of gas.

The L-shaped pipe *D* conveys the gas into the chamber *C C*, figure 4, and thence by the openings *a b c d*, figure 3, into the chambers *A B C D*, the

pressure of which gas between the surface of the water and the divisional partitions, causes a rotary motion to be given to the internal cylinder; and therefore it follows that, in one revolution of the internal cylinder, every part of it must be filled with gas. The capacity of that cylinder being known, the quantity in cubic feet or in any other measure is known also.

E is the exit pipe, which conveys the gas to the burners when the meter is used for ascertaining the quantity of gas consumed in a house or other building, &c., or for conveying it to the gas-holder when it is constructed on a large scale for ascertaining the quantity of gas generated.

On referring to figure 3, which shows the divisional arrangement of the meter, the entrances to and exits from the inner cylinder, we shall see its action more clearly. Supposing the gas to be turned on, and the stop-cock opened which conveys it from the outer case when the opening *a* is just above the water; the opening *d* being at the same time above the water, that part of the chamber D which is above the water will be the first filled with gas, and the meter will be put in motion towards the left hand till such time as the opening of exit from that chamber 4 rises above the water, when the gas which it contains will be allowed to escape into the outer case. But before the opening of exit 4 rises above the water, the opening of entrance *d* into the

chamber D, will have sunk beneath the water, and consequently, as the gas escapes from that chamber into the outer case, its place will be occupied by the water entering into it at *d*, as well as at the centre, which allows a communication of water between all the chambers to the level at which the water stands in the meter.

The opening of exit 4 having risen above the level of the water, the chamber D, as we have already observed, is gradually filled therewith; but before it is so, the chamber A will have been filled with gas, and the chamber B also nearly ready to discharge itself; for, almost as soon as the opening of exit from the chamber D has risen above the water, the chamber A will, by the opening *a*, be nearly half filled with gas, and the opening *b* to the chamber B, will be ready to rise above the water also. The motion of the interior cylinder being uniform, the exit 1 will next allow the chamber A to commence emptying, which will not be entirely accomplished till that chamber has sunk beneath the water at the left hand side of the meter, the gas at the time entering at *b* into the chamber B till that is filled, and the exit 2 opened by its rising above the water: before that takes place, the chamber C commences filling, and fills gradually by the opening *c* till the exit 3 is opened, and, when that is the case, the chamber D will be in the same situation as when the opening of entrance *a* was

just rising above the water, as has already been described. Having described the action of this meter through one entire revolution, it would be but a repetition of the same thing to go further into detail; indeed it would be entirely useless to do so, for if the reader draw a circle upon a card with the radius of that circle which forms a section of the outer case of the meter figure 3, and copy the section of the interior cylinder *A B C D* of the same figure, and connects the centres of the two by a small pin to represent the pivot upon which the interior cylinder works, he will have a simple model of the gas-meter. Let him then fasten a thread of silk across this model, at the height shown by the dotted line, which will represent the height of the water therein; if he then moves the card (which must be cut to the size of the interior cylinder *A B C D* as in the figure) representing the interior cylinder from right to left, he cannot fail to understand the meter's action.

It may not be improper to remark, that such part of the space between the concentric circles formed by the interior cylinder and the external case will, of course, when the meter is in action, be occupied by gas above the level of the water; and therefore the inner cylinder will have a velocity in proportion to the diameter of the exit pipe, or the orifice supplying the burners. Thus, for instance, if a meter of sufficient capacity to supply ten lights be used to

supply five lights, it will in this case make but one revolution in the same time as it would have made two had ten lights been supplied from it.

The meter as above described was found to answer every purpose that was required; but notwithstanding its superiority over the patent gas-meter, the inventor felt desirous of making a meter which would occupy even less room than it did, but as he could not decrease the diameter of the interior cylinder, he adopted the following method, which completely answered the purpose intended; and, with certain deviations from his plan, all rotary gas-meters slight (having the axis upon which they work placed horizontally) have been and still continue to be constructed. We now proceed to describe this improved gas-meter.

Instead of there being a chamber C C, as described in figure 4 attached to the interior cylinder, for the purpose of receiving the inverted pipe D, the chamber of this improved meter is at the centre, see figure 1, Plate XX. By this contrivance the meter, of which figure 2 of same plate is a section, will be one-third less from A to A than one of the same capacity made on the first plan, figure 4. These two sections are of meters which, in one revolution, allow equal quantities of gas to pass through them, and they are laid down from the same scale.

The outer case A A A A, the inner cylinder

BBBB, the entrance pipe D, the exit pipe E, the water-line *c*, &c., figure 2, being the same as already described at pages 368, 369, and 370, preceding, a repetition of their uses, &c., in this place is not necessary. We shall therefore turn to figure 1. EF is a section of the chamber into which the L-shaped D conveys the gas. A, B, C, D are the chambers into which this meter is divided, and are a range of gas-holders acting with a rotary motion instead of a vertical one. These gas-holders receive the gas by the openings *a*, *b*, *c*, *d*, and discharge themselves into the outer case by the openings in the rim of the interior cylinder 1, 2, 3, and 4.

Now, supposing the opening *a* to be just at the top of the water, and the stop-cocks which allow the gas to enter into and to discharge itself from the meter to be opened, the opening *d* being above the water, will allow that part of the chamber D which is unoccupied by water, to be filled with gas, the pressure of which between the surface of the water and the divisional partition R, will cause the internal cylinder to revolve on its axis towards the left hand, which motion will bring the opening *a* above the water; and as that rises, the chamber A will be emptied of water, and the space which the water had occupied will be filled with gas. Whilst this is doing, and prior to the opening *b* rising above the water, the opening of exit 4 will have allowed the gas to escape from the chamber D into the outer

Fig. 1.

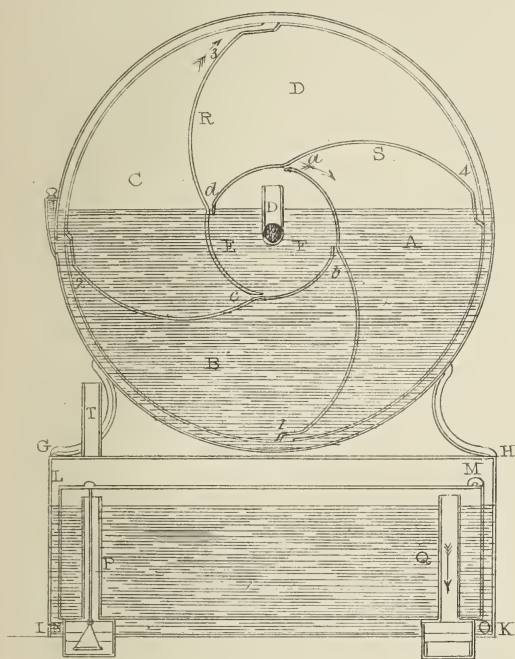


Fig. 2.

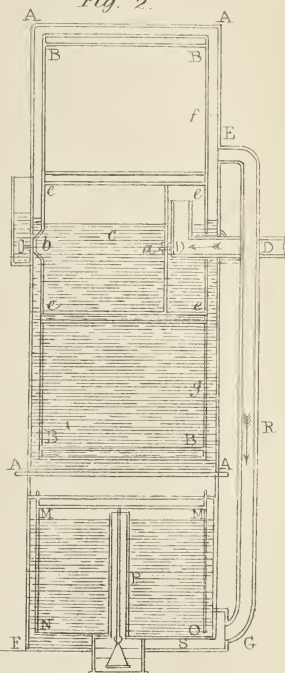


Fig. 3.

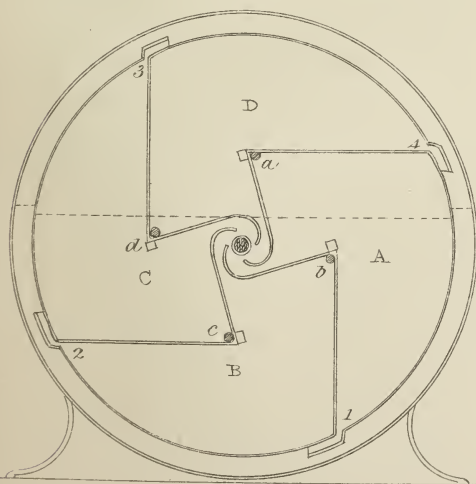
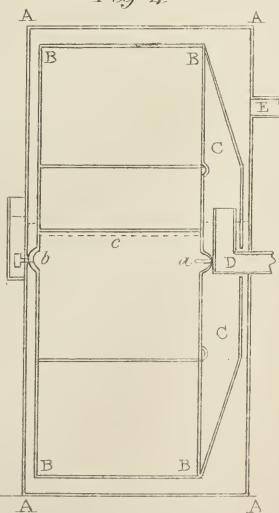


Fig. 4.



Tho<sup>s</sup> S Peckston

London, Pub<sup>d</sup> by E. Hebert, 20<sup>th</sup> February, 1841.



case. The gas will at this time be exerting itself through the opening *a*, between the surface of the water and the divisional partition *S* till the opening *l* is above the water. The chambers *B* and *C* undergo the like operations, till the opening *a* is in the position first described, and, when it is so, the interior cylinder will have made one entire revolution.

We would here, as on a former occasion, recommend the reader to make a model on card-paper of this meter to correspond with figure 1, marking similar parts with similar letters and figures which, having before him, will make the description given more intelligible.

The utility of the gas-meter is now so well understood that there is little occasion for saying much about its mode of operation, as we expect we have said quite enough to make those unacquainted with its internal construction understand upon what principle it acts, and that, if constructed properly, it cannot fail to be a correct measurer. Most large gas establishments have one or more fixed upon their works for the purpose of registering correctly the quantity of gas generated. No gas-work should be without a station-meter, first, because without one it is impossible to know what quantity of gas may be produced, and secondly, because it would act as a constant check upon the stoker, (particularly if so constructed as to mark down the quantity of gas

generated every hour as is frequently done), and we must be aware that were that the only advantage gained it would be an important one; for from idleness or inattention, he might during the night neglect his fires or not charge his retorts properly. In the former case, the heat of the retorts would be so much decreased as to fail in extracting the gas from the coal in a proper time, hence if he drew his charge at the usual hour it would not be half carbonized and the quantity of gas registered by the meter would show that there had been some neglect, for from the manager comparing what gas had been made during the night with what had been made during the same number of hours during the day, he would at once notice the discrepancy, and then ascertain whether the deficiency had arisen from neglecting the fires or using smaller than the usual charges in the retorts. As a matter of course the station-meter would not be accessible to any one save the manager of the works; but the workmen, knowing it would keep a correct account against them of the gas made; would be very careful not to neglect their duty.

We come now to speak of the gas-meter when applied to the purpose of measuring and registering the quantity of gas consumed in houses, &c., where gas-lights are used. In doing so, we hope to make it appear, that burning gas by meter is the most advantageous method for the manufacturer as well

as for the consumer. We shall assume, in the first place, that the gas-meter is a correct measurer, and we consider, when we reflect upon the vast number of gas-meters which have been made (and for many years used), of almost all sizes, with various contrivances of floats, &c., for keeping the water at a certain height, and for shutting off the supply should the surface of the water from any cause fall below its proper level, that in considering the gas-meter a correct measurer, we are not assuming too much. Assuming, then, that the meter measures and registers correctly, it must be evident that the gas manufacturer (with the exception of losses from bad debts) will be paid for all the gas he supplies to private consumers, those who burn extravagantly paying more, and those who burn economically, less than they had been in the habit of paying when they were indiscriminately charged similar prices for similar sized burners, supposed to burn with equal heights of flame, and during a like number of hours : and hence the economical consumer will be benefited. Indeed, when shop-keepers and others burn gas by meter, they have it in their own power to use as little or as much as they please. In private houses, hotels, &c., the gas-meter is indispensable for the time of burning, and the number of burners used at an average can hardly be so fixed as to do ample justice between the Gas Company and the consumer were no meter used ; whereas with the

meter the consumer can light many or few lights as required, the meter correctly registering the quantity of gas consumed in both cases, from one quarter of a year to another, so that it will always show the quantity of gas consumed within some specific period, thus preventing disputes and questions which, without it, must oftentimes arise. By the consumer burning by meter, attending to the height of the flame of his burners, and not keeping them lighted longer than he may find necessary, he will soon find that a considerable saving of expense will be the consequence, on comparing what he may have to pay by meter, with what he might have been in the habit of paying for his gas when he burnt it by contract. We speak of a fair and legitimate way of effecting a saving, without in any way injuring the supplier; we suppose he burns his gas the same number of hours as he burnt it when he paid for it by contract, and that he uses the same number of burners, and we are prepared to say if he does so, he will effect a very considerable saving. In short, we are so persuaded of the utility of the gas-meter, that we cannot fail most strongly to recommend its use in *all* cases, to the parties who manufacture as well as to those who consume the gas, as being most equitable and satisfactory to both parties, and most decidedly in favour of the person who will cause attention to be paid to the lights he may have in his establishment.

We have already noticed that *all* the gas-meters used at the present day are precisely the same in principle, and nearly similar in construction, to the one described by figures 1 and 2, Plate XX. Before we conclude this chapter, we may however add that several attempts have been made (and in two instances very large sums were expended) to produce a “dry meter,” or one that would measure and register the gas by an instrument not containing water or any other fluid ; but as none of the dry meters are used, or likely to be used, owing, first, to a flexible material not being found which will withstand the action of coal-gas ; and secondly, to the difficulties presenting themselves to prevent the formation of such inlet and outlet valves as will work with the requisite degree of certainty, it will not be necessary to dwell further upon them in this place.

Prior to those we have alluded to (which are of recent date), a dry meter was patented by Mr. Malam in 1822 or 1823, but it was never brought into use : he however took out a patent in June, 1835, for a wet meter, which, instead of revolving vertically upon an horizontal axis, revolves on a nearly vertical axis round a pivot upon which the interior revolving drum rests. This meter has, up to the present time, not been tried, except to a small extent, upon gas-works with which the patentee is connected. The specification of his patent may be seen

in "Newton's London Journal," vol. viii., at pages 139 to 144 inclusive, where various figures are given explanatory of his invention. We may here remark of this meter, that we have seen it in action, and carefully examined its construction, and think well of both; consequently, regret it is not more generally known, and that the limits of this work will not permit us fully to describe it: however, as we have pointed out where a full description of this meter may be seen, and as the work is easily obtained (No. 50 thereof, conjoined series, price 2s. 6d., contains the specification of Mr. Malam's patent, with figures of reference), the reader will find no difficulty to prevent his making himself acquainted with the principle upon which it acts and its mode of operation. In perusing Mr. Malam's specification, and noticing the figures of reference, the reader will not fail to observe that he had provided the means, in the event of the water in his meter becoming, by evaporation or otherwise deficient, of supplying such deficiency by means of a reservoir of water placed on its top acting on the principle of a bird fountain. We notice this because, in a patent recently granted for a meter which has been named (after the patentee) "Hemming's Patent Protector Gas-Meter," one of the leading features is a fountain of supply to keep the fluid in which the internal drum works (which internal drum is precisely similar to that of the meters made by all gas-meter

makers), at a uniform or fixed and certain level. When we look at all the advantages the protector gas-meter holds out, we cannot help observing that a reservoir of supply to a meter which works in a fluid (so the patentee states) found to be so little subject to evaporation as to remove almost entirely the defect of a variable level, we are inclined to consider a fountain of supply a needless appendage, however useful it may be, where water is used for the interior cylinder or drum of the meter to work in.

Having made these remarks, we shall observe that the Patent Protector Gas-Meter is, in principle and in construction, precisely the same in all respects as those in general use, with the following exceptions: that is to say, first, a reservoir of supply connected with a self-acting fountain for keeping the fluid in which the interior drum works at a uniform level; secondly, small pieces of zinc attached to the brass-spindle upon which the drum revolves, as well as upon the train of wheel-work connected with the counts for the purpose of neutralizing, by voltaic influence, all chemical action upon the materials of which the spindle and wheels spoken of are composed; and thirdly, adding to the water a sufficient quantity of salt to form a strong brine, which it is well known will not freeze even at much lower temperatures than are ever experienced in this latitude. This is the most recent improvement brought before the public; and, notwithstanding the remarks

which we have deemed it our duty to make, we consider that the means the patentee has adopted for preventing the corrosion of the metal of which the train of wheel-work is composed, will answer the object he has in view ; and that his adopting a saturated solution of sea-salt, instead of mere water, for the drum of the meter to work in, will prevent the inconvenience attendant upon the meters now generally used from congelation during the severe frosts which the climate of Great Britain is sometimes subject to. As regards the gas-meter, we have no doubt but the time is near at hand when further improvements will be made in its construction, in which its action will be simplified and its bulk diminished, and consequently its cost lessened. Meanwhile we are perfectly satisfied that all the gas-meters manufactured by respectable tradesmen may be relied upon as affording correct statements of the gas which passes through them ; for should the water in any rise above a certain level, it will overflow the L-shaped pipe, and thus prevent the gas from entering into, and consequently passing through, the meter ; or should the water, by evaporation or otherwise, sink too low, a float-valve will fall upon the entrance pipe, and, in like manner, nearly instantly shut off all communication from the meter, so that in neither case can any gass pass through it till the evil be removed.

## CHAPTER XV.

On the Governor, the Regulator, and Gas-Moderator.

THE unfair manner in which many of the customers of gas-light companies burnt their gas (previous to the gas-meters being so very generally adopted) led the persons who had the management of gas-works to adopt measures for preventing the possibility of its occurrence. The instrument for effecting this object was originally called "*the governor*," and, more lately, also named "*the regulator*." The first instrument of this kind which appears to have been offered to the notice of the public was invented by Mr. Samuel Clegg, and for it he obtained a patent, under date the 9th of December, 1816. His invention is described in No. 176 for January, and No. 177 for February, 1817, of the second series of the "Repertory of Arts." If the reader refers to the description therein contained, he will understand the properties of the governor, and perceive that its action tends to keep the pressure constantly adequate to the demand. It will effect the regulation in an equal degree when the inequalities of pressure are occasioned either by an increased or a diminished consumption of gas, and also either by an increased

or a diminished supply ; for the operation of it is to adapt the orifice through which the gas passes to the quantity required to pass, so as to keep the volume discharged, and consequently the pressure under which the gas may issue through each respective burner, under all circumstances, nearly the same. For the purpose of making the reader who cannot easily refer to the numbers of the “Repertory of Arts,” understand the construction and principle upon which the governor acts, we have given a vertical section of one at Plate XXII. of this work, figure 9. *A B C D* represents the outer case, which may be made of sheet-iron, copper, or strong tin-plates, with the top and bottom closed, all which ought to be japanned inside and outside. *J K L M* shows the form of the small gas-holder, which is rendered more buoyant than it otherwise would be by the air-vessel marked \* \* which goes round its bottom. *E*, the inlet pipe, or that which brings the gas into the governor ; *F*, the exit pipe. The conical valve *c*, attached to the bottom of the upright spindle *G*, rises and falls with the gas-holder, so as to contract or enlarge the orifice in the disc *I H* (fixed in the pipe marked *a a*, above the entrance of the pipe *E* into it), as the gas-holder ascends or descends by the passing in or out of the gas. *g h* is a shallow cup into which the outer case is fixed at the centre of its bottom, or base. *d d e e* are guide-rods, for ensuring the vertical rise of the gas-holder,

upon which slide the brackets *ffff*, attached to the outside of the gas-holder.

If we suppose the governor to be connected to the service pipe by means of the pipe E, and with the pipe leading towards the burners, by means of the pipe F, preparatory to bringing it into action, it will be necessary to remove the lid at the top, and to pour water into the case, or tank, till it rises to within an inch of the top of the upright pipe *aa*. This being done, the top must be put on, and made gas-tight by a luting of bees'-wax and tallow; the nuts on the top of the guide-rods must also be screwed up tight, and when this is effected, the governor is ready for being used. The first thing to be done, then, is to open the cock between the pipe E and the main, which is placed on the service pipe, and usually called the "main cock." When that is done, if the gas-cocks between the governor and the burners be gradually opened, they will allow the gas to pass through the governor and escape through the orifices of the burners where it is to be consumed. It is evident that, under such an arrangement, if the pressure from the street-mains be, from any circumstance, increased, the gas will flow with more rapidity into the gas-holder of the governor. This increased impetus raises the gas-holder in the tank, and, consequently, the cone *c* along with it; by this means lessening the orifice of supply at I H, so that the supply of gas to the

burners remains nearly unchanged, and the flame at nearly its former height. The governor, if constructed to work at such a pressure as would adequately supply a certain number of burners, would prevent any consumer to that amount from burning his gas too high, if he felt inclined so to do, for he would always be obliged to open his cocks to their full bore to enable him to obtain a light about three inches in height;—higher than which they would not burn, let the pressure at the manufactory be increased to what it might, as is evident from what has been already stated. When the governor is used for supplying ten lights, the cone should be about three inches in length, and its base about five-eighths of an inch in diameter: for four or five lights, the cone need not be more than two inches and a half long, and half an inch in diameter at its base. The pipe of supply, E, and the exit pipe, F, should, in either case, be three-quarters of an inch in diameter.

Another description of governor, or regulator, was constructed by Mr. Malam, soon after he had invented the improved gas-meter. It was parallelopipedal in shape, and served as a base, or pedestal, for the meters of his invention to stand upon. GHIK, *Plate XX., figure 1*, is a longitudinal vertical section of this regulator, of the same length as the diameter of the gas-meter with which it is used. LMNO is a similar section of the gas-

holder (constructed so as to act at a certain pressure), which acts upon the pivot shown at M. P is an upright pipe, which rises nearly as high as the top of the gas-holder, when that is in a horizontal position. Immediately over the centre of this pipe, in the top of the gas-holder, is fixed a small hook, to which is hung the wire attached to the cone, so as to act freely in all directions. The wire for supporting the cone is formed into two links, the lowermost of which is connected to a hook rising from the apex of the cone. Thus, as the top of the pipe is entirely open, there cannot be any apprehension of the wire being bound or obstructed, so as to prevent the cone from acting freely. The vertical pipe Q is that by which the gas escapes towards the burners. The manner in which the gas is brought into this regulator will be better understood by consulting the vertical transverse section at figure 2. A A F G of that figure is a section of the outer case, of a breadth equal to that of the meter with which it is used. L M N O is a section of the gas-holder, acting upon the pivots shown at L and M. The upright pipe P, with the wire and cone, have already been described in the explanation of figure 1. S, figure 2, represents the pipe which conveys the gas from the gas-meter to the regulator by means of the pipe R, or from the service pipe when the regulator is used without a gas-meter. A pipe similar to that shown at S is also attached

to the upright pipe **Q** (figure 1), for conveying the gas from the regulator towards the burners. At the bottom of the regulator, immediately beneath the pipes **P** and **Q**, are soldered two screwed brass rings, of about two inches in diameter, upon which, when the regulator is in action, are screwed two brass caps, having a short piece of pipe brazed into the centre of each (which is cut out for the purpose), with a cock for drawing off any condensation which may descend into the pipes. The pipe marked **T**, figure 1, is soldered upon the top of the outer case of the regulator over a hole made therein. This pipe is open at the top. It is for the purpose of allowing the regulator to sustain a greater pressure than it possibly could were the top entirely closed.

On examining the sections of this regulator and comparing them with the section of the governor (figure 9, Plate XXII.), the reader will perceive how far they differ in arrangement. If we begin with the gas-holder, we shall observe that the base of the regulator is much greater than that of the governor, the latter being, for four or five lights, not more than six inches in diameter, or an area of about twenty-eight square inches; whilst, in the regulator, it would be a rectangle, dimensions ten inches in length by five inches in breadth, or an area of fifty square inches. And as the length of the gas-holder in the regulator is considerable, and

that acting as a lever upon the fulcrum at M, any change of pressure is immediately felt and checked; for there cannot possibly be that friction in its action which occasionally impedes the operation of the governor. The cone of the regulator is not made so long and taper as the cone of the governor, consequently a very small rise or fall of the gas-holder is sufficient to bring it sensibly into action. As the action of the cone in the regulator, as well as of that in the governor, though somewhat different in each case, is the means of keeping the lights at a proper height, after what we have said about the governor, we need not add any more here relative to the regulator, as a mere inspection of the figures 1 and 2, Plate XX., and figure 9, Plate XXII., renders our doing so needless.

*Figure 10, Plate XXII.,* is a vertical section of a governor, or regulator, adapted for being placed upon the leading main from the gas-works towards the town or district to be supplied with light therefrom. The figure is supposed to represent the inlet pipe A and the outlet pipe B as each being four inches in diameter, and the centre pipe, in which the cone and descending arrow are shown, of the dimensions as given when describing figures 11, 12, and 13, which show said pipe drawn to a larger scale. The tank in which the gas-holder of this governor works is represented as built of brick laid in Roman-cement; and, if so, it will be best that

the side of the tank should not rise more than about six inches above the floor of the building in which the governor is placed. When the inlet and outlet pipes are of four inches diameter, a tank three feet diameter and two feet three inches deep will be sufficiently large for the gas-holder to work in. The bottom of the tank is of solid brick-work (about seven courses in thickness), the square upright centre pipe (figure 11) resting with its bottom upon or in the second course. Every course of this work should be well filled in with Roman-cement, made of the consistence of grout. The side walls C C are also laid in Roman-cement; and, for greater security under the bottom, as well as round the tank outside, puddle should be used, as directed when speaking of brick or stone tanks for the larger gas-holders. The bottom and upright part of the tank inside should also have a coat of Roman-cement applied of about one inch in thickness. The gas-holder may be made of No. 20 Birmingham wire-gauge iron, or of strong tin plates; its diameter, in this case, would be two feet six inches, and its height two feet three inches. The top of it had better be of a convex shape. Upon the crown and over the centre of the gas-holder is placed the cylindrical vessel D D, intended to be filled with water, and from three points of the upper edge of which (in which S-hooks are inserted) the gas-holder is suspended by means of the cords which

pass over the pulleys shown, and then are connected to a case **E**, containing shot, which works upon a rod *a*, attached to the top of the gas-holder, directly over its centre outside, which acts as a guide-rod, causing the gas-holder to rise or fall vertically. To the centre of the crown of the gas-holder inside is secured the rod which supports the cone, which rises and falls with the gas-holder, so as to close partially or entirely the conical opening (shown at figures 11 and 12), according as more or less gas may be called for. The use of the vessel **DD** at the top is to decrease the pressure gradually as the shop and private lights are turned off, so that when all are put out, the gas-holder may work at a proper pressure for supplying public lights, and lights that burn all night only, which object is effected by the following means:—When the governor is first brought into use, the vessel **DD** is filled with water, and a sufficient quantity of lead-shot is put into the counter-balance box **E** to cause the governor to work with a sufficient pressure for affording a proper supply of gas to the greatest number of burners that may be lighted at one time during the night. To the bottom of the vessel **DD** is connected a piece of half-inch drawn tin tube, which extends over the angle at the top of the gas-holder, and to the end of it is attached a half-inch brass cock, which is kept shut till the shops begin to close. The workman then opens the cock, so as to

allow the water to escape very slowly from the vessel DD into the tank, till the vessel is entirely empty, or till the pressure-gauge, placed in the governor-house, indicates the pressure which is needful for the night when the cock is closed, and then no further adjustment of pressure is required. This mode decreases the pressure much more equably than it can be effected by hand, when the supply is checked by decreasing the orifice of the main slide-valve. The action of this governor being similar to that for private houses, &c., already described at page 385, when speaking of figure 9, no further remark on that head is here required.

*Figure 11* is a vertical section of the upright square pipe for conveying the gas to and from the gas-holder drawn on a larger scale than in figure 10, upon which the dimensions are marked. The gas enters by the pipe A, and rises up the partition marked C, passing through the conical aperture in the flanch (figure 13), which is jointed to the top of the pipe. From the gas-holder the gas descends down the partition E, (which is separated from the partition C by a partition-plate D, cast therewith to within about two inches of the bottom,) and thence by the pipe B towards its destination. To the bottom is jointed and secured, by screw bolts, the blank flanch *b c*; and previously to the governor being used, water is poured down this pipe till it rises as high as the dotted line *a a*,

consequently the partition-plate D is sealed, and the gas entering by the pipe A, cannot find its way to the pipe B without passing through the conical opening *e* into the gas-holder, and thence down the partition C. *i* represents the rod by which the cone *j* is suspended from the centre of the crown of the gas-holder.

*Figure 12, Plate XXII.* In this figure the outline marked *d, f, h, b, g, c* represents the plan of the flanch at the bottom of the pipe (figure 11), and of the blank flanch bolted thereto. \*\*\*\* represents the top of the pipe, showing the plan of the partitions C and E and the position of the partition-plate D; also a plan of conical opening marked *e*, as shown in section in figures 11 and 13.

*Figure 13, Plate XXII.* Vertical section of a flanch with a conical opening for the cone *j* figure 11 to work in. It is to be jointed over the partition C, figure 11, the cone being first dropped down that partition before the gas-holder is suspended. The rod *i* must have near its upper end a collar, and a thread above it to pass through the top of the gas-holder at the bottom of the vessel DD, where it is secured in its place by a nut and washer, &c., a little tow, well soaked in tallow, being first twisted round the spindle beneath the washer, so that when the nut is screwed up, the gas-holder may, where the spindle passes through it, be perfectly gas-tight.

*Figure 14, Plate XXII.*, is a vertical section of the gas-moderator, as manufactured by Messrs. Platow and Co., 40, Hatton Garden, and 145, High Holborn, London. The object of the manufacturers of the gas-moderator is, by that machine, to render the flames of gas-burners steady and uniform throughout the evening, and to prevent those fluctuations of light occasioned by any sudden increase or decrease of pressure. In short, it is intended to produce precisely the same effects as the governor already described by figure 9, Plate XX., at pages 384, 385, and 386. The gas-moderator is much more portable than the governor, and can be attached to a single burner, in which case it is not more than two inches in diameter, and about as much in height. It is made ornamental in its appearance. One for regulating from eight to ten lights is not more than about three inches in diameter, and about three inches in height. In *figure 14, Plate XXII.*, A is the gas inlet pipe; G the valve regulating the supply of gas to be admitted; C the rod which works the valve (something similar to the key of a wind instrument); DD a flexible membrane (or diaphragm) coated with gold-leaf and fitted gas-tight to the rod C above and to a metal disc below; E a spiral spring; F an adjusting thumb-screw by means of which the situation of the valve G must be so adjusted as to afford just a sufficient supply of gas to the burner

or burners when there is the least pressure upon the mains. Should an increase of pressure be put upon the mains, or should an increase of pressure occur from the putting out suddenly of many lights, it will be immediately felt in the gas-moderator, and acting upon the upper surface of the diaphragm, D D, will press it downwards. The rod C, being connected with the diaphragm, will be carried downwards with it; and as it is also attached to the crank that works the valve, the valve G will be pushed towards the aperture through which the gas enters, so that the opening will be less and the quantity of gas admitted into the moderator under this increased pressure will not be more than when the pressure was less and the aperture greater. On the pressure being again diminished, the spiral spring pushes up the diaphragm, consequently the rod, which acts upon the crank of the valve G, draws the valve back, and thus enlarges the aperture through which the gas enters. In this figure, B represents the outlet which is furnished with a union joint for connecting to the pipe which leads towards the burners. The inlet pipe A is also furnished with a similar union joint.

Either the governor or the gas-moderator may be usefully employed in churches or other places of worship, and in places of public resort to prevent the adjustment of the lights by means of the regulating or main cock, by which operation sometimes

a needless alarm is created which has occasionally been attended by very serious consequences. In shops, and more particularly for the lights in shop-windows, where a sudden flaring up of the gas might be injurious to goods there exhibited; in private houses, hotels, warehouses, manufactories, and workshops, where an equal supply to the burners on each floor is of importance, the governor or gas-moderator ought to be used. Either will benefit the consumer by keeping all his burners at a proper height so as to prevent smoke from the gas, too much heat being generated, and any risk arising from fire. Indeed, it must be evident that an instrument constructed on such principles that the consumer may adjust it so as to cause all the gas-lights he may have in his establishment to burn with a certain height of flame and no more, whether he has fifty or five or one lighted, must be very valuable, as it will save him from much personal attendance, and be a complete check against carelessness or the wasteful expenditure of gas by any persons in his employment.

## CHAPTER XVI.

## On Tests.

IN the chapter on the purification of gas, it was stated to be necessary that tests be occasionally employed for ascertaining whether, by the purifying process, the gas is effectually deprived of the sulphuretted-hydrogen gas, carbonic-acid gas, &c., which are evolved with the proto and bi-carburetted-hydrogen gases in the retorts. That this should be done frequently appears requisite; for it is absolutely necessary that the manufacturer should supply his customers with pure gas only; and unless he causes tests to be frequently taken, it is next to impossible for him to know whether the gas he may supply be pure or impure.

In some manufactories, a contrivance has been adopted intending to indicate and register the impurities of the gas, and at the same time to denote the periods when they occur. It consists of a circular card fixed upon an axis, communicating with a time-piece. Upon this card are described three circles, each divided into twenty-four equal parts, by lines radiating from the centre. The outer circle

is coated with acetate of lead, in solution, or some other of the usual tests for detecting sulphuretted-hydrogen gas, and the middle one with tincture of litmus, or with a decoction of red cabbage for detecting carbonic-acid gas. Upon each of these circles a very small jet of gas is made to play constantly. The inner circle is divided into twenty-four equal parts, marked from one to twelve DAY, and from one to twelve NIGHT, and the card performs its revolution in twenty-four hours, consequently the impurities and the time when they happen are said to become exactly registered, and that, by changing these cards daily, a perpetual register is obtained. From our own experience in the manufacture of gas, we should be much inclined to doubt that the method we have alluded to would indicate the time when the most impure portions of gas would be passing through the orifices spoken of, and playing on the card, for the action of such gases, from their great diffusibility in the atmosphere, could not be confined to a point, consequently, unless the card were of large diameter when the gas was very impure, its action upon the card would extend itself over a considerable portion thereof, and in consequence leave the time of its greatest impurity but very faintly indicated. A much more certain method for securing a constant supply of pure gas is to have a small pipe connected to the top of each of the purifiers, fitted with a stop cock, (which we shall designate the "*test*

*stop cock,*") and a very small single jet burner, or so that a piece of drawn tin or brass tube, bent at right angles, can be attached to the cock by means of a union joint. At this place, from time to time, the gas ought to be tested by one or other of the modes about to be mentioned, till the test solution or test paper indicates a very trifling departure from purity, and so soon as that is the case the purifier must be shifted. If the first trial be carefully noted down, and the manufacturer continues to use the same number of retorts, the same description of coal, and works with similar charges as to time and quantity of coals, he will not find it necessary to take tests except once or twice between the times of his changing the moistened lime or lime and water in his purifiers, that is to say, about an hour before the time he thinks (from a week's very careful observation) the purifying medium has become so saturated with impure matter as to be no longer able to perform the purifying process perfectly.

We now proceed to describe the tests we have been in the habit of using for detecting sulphuretted-hydrogen gas, carbonic-acid gas, and ammoniacal gas.

*Tests for detecting sulphuretted-hydrogen gas.*

1. Nearly fill a two-ounce phial with distilled water, and add thereto as much acetate of lead as it will take up: shake up the mixture, and then, with a

camel's-hair pencil, wet therewith a piece of writing-paper. When this is done, open the "*test stop-cock*" already mentioned, and hold the side of the paper wetted with the mixture for a few seconds close to the aperture of the single jet burner, so that the gas may play upon it. If the gas thus tested contain one cubic foot of sulphuretted hydrogen in a volume of 20,000 cubic feet of carburetted-hydrogen gas, it will produce a sensible discoloration.

2. Add to two ounces of distilled water four grains of nitrate of silver, and so soon as that is dissolved, it is to be applied in the same way as the first test. It is a more delicate test for sulphuretted-hydrogen gas than the solution of acetate of lead. The phial in which this test is kept should be coated with tinfoil, to protect the test from the blackening action of the rays of light.

The above tests are what we have been in the habit of using for detecting the presence of sulphuretted hydrogen, and in our practice we have generally used pieces of writing-paper about three inches square, noting at the back of them the time when the test was taken. So soon as the test was taken, the test paper was laid between the leaves of a small blotting-book kept for the purpose, and thus became a register of the purity of the gas at the times the tests were taken. In this way we may ascertain the presence in coal-gas of extremely small quantities of sulphuretted hydrogen, and form a tolerably near

estimate of its proportion, when too minute to be otherwise measured, by comparing the shades of colour given with a series that has been prepared for the purpose, by exposing slips of card or writing-paper prepared as we have described, to mixtures of sulphuretted-hydrogen gas and common air in known proportions. It will be necessary to keep the nitrate of silver tests, when discoloured by the action of the sulphuretted hydrogen, in a book, excluded from the light, as they are liable to change of colour from exposure thereto.

3. Mix three grains of acetate of lead with two ounces of distilled water in a wide-mouthed bottle, by shaking the mixture well together, and it will have a milky appearance. If it be then taken to the "*test stop-cock*," and the bent-pipe we have already mentioned be inserted into the bottle for about half a minute, during which time the gas to be tested will bubble up through the mixture—if the gas is freed from sulphuretted hydrogen, the test will remain white and milky; but if it contains sulphuretted hydrogen, it will appear dark and cloudy. This is a delicate test for discovering minute portions of sulphuretted-hydrogen gas, with which it forms a black precipitate.

4. Into a wide-necked bottle put an ounce of distilled water, and then impregnate it with the gas which is desired should be tried, by blowing it through the water, as described in the third or pre-

ceding test. If it contains sulphuretted hydrogen, it will produce a foetid odour, resembling the smell of putrefying eggs. Should a single drop of the solution of nitrate of silver, mentioned as the second test, of acetate of lead, mentioned as the first test, or of chloride of bismuth, be dropped into water impregnated with sulphuretted-hydrogen gas, in the manner already described, it will instantly be rendered black.

5. Impregnate distilled water with the gas to be tried in a wide-mouthed bottle, and then let it be poured upon a plate, or into a small evaporating basin. Hold close to the surface a slip of paper wetted with a solution of nitrate of silver. If sulphuretted-hydrogen gas be present, it will escape from the fluid and cause the paper to be blackened.

*Test for detecting either sulphuretted-hydrogen gas or carbonic-acid gas.*

Tincture of litmus (the natural colour of which is a dark blue, inclining to purple) may be employed for detecting either of the above gases, the action of either of which, upon the tincture of litmus, produces a redness. If a solution of pure barytes be mixed with the tincture thus coloured by sulphuretted-hydrogen gas, no precipitate will be formed; but if the change of colour had been effected by carbonic-acid gas, it will immediately become turbid, and a soluble precipitate will fall down with effer-

vescence in pure dilute muriatic or nitric acid. By this criterion the action of carbonic-acid gas upon litmus from that of sulphuretted-hydrogen gas may be distinguished.

*Tests for detecting carbonic-acid gas.*

1. If an ounce of distilled water be tinged slightly blue by tincture of litmus, and then impregnated with the gas desired to be tried, if carbonic-acid gas be present it will speedily produce the reddening effect.

2. Into an ounce of distilled water, impregnated with gas, let fall twenty or thirty drops of sulphuric acid. If carbonic-acid gas be present, many minute air-bubbles will be rapidly disengaged.

*Test for detecting ammoniacal gas.*

To determine whether the gas has acid or alkaline properties (the latter are characteristic of the presence of ammonia), a small slip of litmus-paper may be first introduced into it. If it be reddened, the gas must be acid; if not changed, a slip either of litmus-paper reddened by vinegar, or of turmeric-paper, may be introduced into it, when the alkaline nature of the gas will be indicated by the usual change of colour to blue or brown. Acid and alkaline gases cannot both exist together in the same mixture, as they immediately condense each other into a solid form.

Were it necessary, many more tests might be

added ; but these already mentioned are amply sufficient for all practical purposes. Should the reader, however, be desirous of pursuing his inquiries still further into this subject, we refer him to the 2nd volume of Dr. Henry's "Chemistry," or to Dr. Reid's "Chemistry," in either of which works he will find abundant information relative to chemical re-agents, or tests.

## CHAPTER XVII.

On the Chemical constitution of Coal-Gas. Observations upon its applicability to Illumination and other uses.

IF we consider the qualities of coal-gas and the various other products, gaseous, liquid, and solid obtained from pit-coal by distillation in close vessels, we are led to conclude that it is composed of carbon, hydrogen, azote (or nitrogen), oxygen, sulphur, some earthy matter, and about one per cent. of hygrometric water. That such are the component parts of coal, found by its decomposition by heat, was an opinion long ago entertained by several eminent chemists; but the most exact proportion of each ingredient in the composition of specimens of divers coals from the great coal basins, has been but very lately ascertained by chemical analysis. We are indebted for the most perfect elucidation of this very important subject to the gas manufacturer, to the researches of Mr. Thomas Richardson, aided by Professor Liebig. As the bounds prescribed in this work do not allow us to enter into such details as those chemists give, we refer the scientific reader to the 13th volume of the "London and Edinburgh Philosophical Magazine," page 121, for August, 1838; or the "Transactions of the Natural History

Society of Newcastle-upon-Tyne," vol. ii., page 401, in which works the comparative quantities of the constituents of coals of different localities are stated at great length.

In the process of the distillation of pit-coal, in order to obtain the greatest quantity of the carburetted hydrogens, we find that when it is acted upon by the heat most appropriate for its decomposition, a red heat visible in full daylight, the zero point of Wedgewood's pyrometer, or  $1077^{\circ}$  Fahrenheit, the following gaseous and vaporous products, partly in mechanical, partly in chemical, mixture, are evolved, viz., pure hydrogen, sub-carburetted hydrogen (1 atom carbon + 2 ats. hydrogen), bi-carburetted hydrogen (1 at. carb. + 1 at. hydr.), aqueous vapour (1 at. hydr. + 1 oxygen), ammonia (3 ats. hydr. + 1 at. nitrogen), carbonic-acid gas (1 at. carb. + 2 oxyg.), (these two last-named products speedily coalesce and form carbonate of ammonia), carbonic oxide (1 at. oxy. + 1 carb.), sulphuretted hydrogen (1 at. sulphur. + 1 at. hydr.). The proportion of these products varies considerably according to the different decomposing heats the coal is subjected to, as also according to the respective descriptions of coal used. All the above-named products, however, and a residuum of about 60 parts of solid carbon and other matter, or coke, in 100 parts of coal, constantly attend the distillation of pit-coal in close vessels; but from the inadequacy of the simple re-

torts, arising from the extent of their heated surface being insufficient to diffuse upon the vaporous products nascent from the coal, the quantity of caloric requisite to disengage the greatest possible quantity of the carburetted hydrogens therefrom, much of those valuable matters, into the composition of which carbon and hydrogen enter, are merely volatilized not decomposed, and leave the retort in a state of vapour, as tar, ammonia, and water. The obviation of this improvidence is the object of a patent, which bids fair to cause a sensible revolution, from its utility and simplicity combined, in the expense consequent on the present mode of generating light-gas, the merits and a description of which patent will be discussed and given in the next chapter.

We are not to suppose that pit-coal is the only substance which affords carburetted-hydrogen gas. It is found ready formed on the surface of stagnant waters and in marshes. In hot weather we may observe large bubbles thereof rise through the former. This gas may be collected. For distinction's sake it is called the carburetted-hydrogen of marshes.

It contains, in the purest state in which we can collect it, about twenty per cent. of azote. When any kind of vegetable matter is submitted to such a heat as is necessary to decompose it, it gives out carburetted-hydrogen gas, and the proportion thereof is greater when the process is carried on in close vessels. Charcoal, wetted with water and submitted

to the action of heat in a crucible or earthen retort, will produce a gas which consists partly of carbonic acid and partly of carburetted hydrogen. This gas is also procured by making spirit of wine to trickle through red-hot tubes, or by distilling camphor therein. In short, carburetted-hydrogen gas is obtained by distilling, in close vessels, either coal, oil, wood, wax, or tallow, or all animal and vegetable substances, into the composition of which carbon and hydrogen enter. There is a curious variety of carburetted-hydrogen gas obtainable from ether or alcohol, which, when brought into contact with chlorine gas, generates an oil that is heavier than water, whitish and semi-transparent; and which, if kept, becomes yellow and limpid. It has a fragrant smell, a sweetish taste, and is partly soluble in water, to which its peculiar smell is imparted. This gas has, by some, been termed oily carburetted hydrogen; by others bi-carburetted hydrogen (or olefiant) gas. It is composed of carburetted hydrogen, super-saturated with carbon. In the distillation of most kinds of coal, a portion of this species of gas always comes over with the common carburetted hydrogen: it must be evident that the coals which yield the greatest quantity thereof will always best answer the gas-light manufacturer's purpose, for the illumination afforded by coal-gas is chiefly produced by the incandescence of particles of carbon precipitated, in the flame, and consequently that gas which has

the most carbon in its composition possesses the greatest illuminating power.

The gas produced during the first stage of the distillation of pit-coal is heavier than that evolved during the latter part of the process, but even then it is very much lighter than atmospheric air. We may state the average specific gravity of carburetted-hydrogen gas obtained from coals (the heaviest about  $\cdot 650$ , and the lightest about  $\cdot 406$ ), at  $\cdot 528$ . When procured from oil, it varies from  $\cdot 939$  to  $\cdot 700$ , showing an average of  $\cdot 8195$ .

We know, from the results of many experiments made for the purpose of ascertaining what quantity of gas could be obtained from a given quantity of coal-tar, that one pound thereof yields about ten cubic feet of carburetted hydrogen, mixed with much olefiant gas. The number of cubic feet of gas obtainable from one pound of coal-tar, as above-mentioned, is the average quantity which was produced by the distillation of coal-tar in vessels of a syphon shape, lying nearly horizontally. The tar was allowed to enter the distillatory vessel, near the mouth-piece of the upper leg, and to trickle over a continuous red-hot surface till its decomposition was properly effected.

Many individuals have attempted to generate gas on a scale adequate to illuminating purposes from coal tar; amongst others the Marquis Montauban recommends that the coal-tar be placed in a vessel

with the requisite quantity of water, which mixture is to be kept constantly agitated or stirred. This vessel is to be placed above the distillatory vessel, so that the mixture of tar and water may enter into it in very minute quantities, through a bent-pipe (syphon shaped), so fixed as to be kept always sealed with the mixed fluid to prevent the escape of gas from the retort. This contrivance formed a part of the Marquis's patent taken out in February, 1838, for improvements in gas apparatus; the specification and drawings of which may be seen in "Newton's London Journal," conjoined series, No. 82, for January, 1839. The Comte de Val Marino has recently endeavoured to combine the vapour of coal-tar with aqueous vapour for the purpose of procuring from the mechanical mixture of the two, carburetted-hydrogen gas. He uses three retorts, one of which is supplied with water from a syphon; another contains coal-tar, the steam from one and the vapour from the other are to pass simultaneously into the third, where the steam and vapour combine; and that combination is resolved by heat into carburetted-hydrogen gas. This operation, though feasible in theory, cannot be carried out in practice on account of very many weighty objections.

Having alluded to the production of carburetted-hydrogen gas from coal-tar, we return to what is our more immediate object, the procuring of it from coal, and this leads us to remark, that if we are de-

siours of working the retorts to advantage, they should always be kept at a bright cherry-red heat, visible by day-light. Gas of the best quality in the greatest quantity is thus produced. Here we must stop, and not by any mistaken notion increase the temperature to a higher degree; for, if we bring it to a white heat, the retort is in danger of being melted, and the gas given out by this over-dose of caloric; from the operation of many chemical affinities called thereby into action, is chiefly a mixture of carbonic oxide and hydrogen gas, yielding a bluish flame of but small illuminating power. Some of the species of Newcastle coals abound with pyrites, or sulphuret of iron; these coals when distilled produce a considerable portion of sulphuretted hydrogen, and such coal-gas consequently requires great attention to be paid to its purification.

In the "Repository of Arts," vol. ii., No. 36, page 341, is an account of the quantity of carburetted-hydrogen gas obtained from wood, by Messrs. Sobolowsky and Horrер of St. Petersburg, and in the first number of the "Quarterly Journal of Science and the Arts" is a paper by Mr. Brande, on the application of coal-gas to illuminating purposes; he mentions the quantities of gas obtained from coal, from the common willow, from the mountain-ash, from white-birch, and from hazel-wood, all well dried, and also from writing-paper. The results are of little value to the practical man, and are alluded

to only for the purpose of calling the attention of the curious towards them.

With respect to the superiority of light afforded from carburetted-hydrogen gas, it may be observed, that it has a decided advantage over other lights; for it has been ascertained that there is considerably less carbonic acid produced by its flame than by the flame of oil, tallow, or wax, and consequently on the score of health, it is more adapted to small or ill-ventilated apartments. Dr. Henry states that 100 cubic inches of carburetted-hydrogen gas require 220 cubic inches of oxygen for their combustion, and produce 100 cubic inches of carbonic acid: 100 cubic inches of the same gas obtained from wax, require 280 cubic inches of oxygen, and produce 137 cubic inches of carbonic acid; and 100 cubic inches of the same gas, procured from lamp-oil, require 190 cubic inches of oxygen for burning, and produce 124 cubic inches of carbonic acid. Can any proof be desired more decisive than the above (setting aside its economy) in favour of using gas-lights? But to produce good light, it is necessary that the gas should be well purified; for if it is not deprived of the sulphuretted hydrogen, it emits sparks, and produces, when burnt, a portion of sulphurous acid by the union of the oxygen of the air with the sulphur precipitated during the process of combustion.

Although coal-gas, if allowed to escape unburnt, emits a disagreeable odour, yet this circumstance

argues nothing against the use of it; for, we are well aware, if a candle or lamp be blown out, during the time the wick of either may remain ignited, a smell equally disagreeable is produced. It is not intended that gas should be allowed to escape unburnt, and it is most satisfactorily established, that during its combustion (if properly purified) it is void of all smell whatever. It may be considered that the smell of unburnt gas is a fortunate circumstance rather than otherwise; for whenever there may happen to be a leak in the pipes or gas-fittings, thereby it is easily found; whereas, if the gas were void of smell, leaks might exist, and in some cases, the most serious accidents occur from the explosive nature of the gas when mixed with atmospheric air, in the proportion of one part by volume of the former, to nine of the latter, and in a close place, should a light happen to be brought into contact with the mixture. We therefore consider, that any attempt to deprive coal-gas of its smell altogether, would render the use of it likely to be dangerous.

As to the possibility of an explosion taking place under ordinary circumstances, when we consider the quantity of gas requisite to form an explosive mixture with common air, we need hardly apprehend it except in very small and confined places. A room fifteen feet square, and nine feet high, if entirely closed, would require an hourly escape of five cubic

feet of gas into it for nearly forty-eight successive hours, in order to be filled with an explosive mixture. But in rooms having a fire-place, doors and windows not fitting very closely, were there an escape of gas, the stop-cock to a burner having been left open, or from leaks, a very considerable time must elapse before a sufficient quantity of gas can escape and mix with the air in the room so as to make an explosion inevitable on a person with a light entering therein. We opine that, under these circumstances, an explosion would hardly take place, and indeed the experience of many years fully justifies us in this opinion.

Coal-gas possesses one great advantage over all other artificial lights, inasmuch as it may be made to burn in any direction, and thus to throw the strongest rays of light upon the spots where they are most wanted, a thing very difficult to effect wherever lamps or candles are used. By turning the cock which supplies the gas-burner, a brilliant flame can be instantaneously produced; and that again, in as short a time lowered to such a degree as scarcely to be perceived. In either case the light will remain for any length of time without any variation of height or intensity of flame, provided the pressure or supply of gas remain the same. The application of gas-lights for the purposes of lighting streets, churches, chapels, houses, &c. &c., is now too well known to require any details thereof; we may, how-

ever, notice that we still are of the opinion expressed in the former editions of this work laid before the public, in which we stated, that it might be advantageously used in light-houses, and suggested means for distinguishing one light-house from another merely by the varied arrangement of the lights.

Coal-gas has of late years been applied to the heating of churches, chapels, shops, counting-houses, &c., instead of stoves, hot-air flues, steam, or hot-water pipes, and has been found to answer the purpose intended. It is burnt in stoves constructed for the purpose, of such different sizes as the size of the place to be warmed may render necessary. For an ordinary-sized room, a gas-heating stove, twelve inches diameter and about two feet in height, will be sufficiently large: it may be constructed of cast or plate-iron, with a register at the top, and open at the bottom. In the interior near the bottom is a brass pipe formed into a ring, and perforated with small holes about an inch apart, this ring being connected to a pipe leading from the service pipe. When the stove is required to be used, the gas is turned into the circular pipe and lighted, and the heat generated ascends between the outer case and an internal cone through the register at the top, whence it diffuses itself equably over the apartment, the temperature of which can be regulated to precisely what may be desired, by increasing or decreas-

ing the gas flame by means of the stop-cock. This is a very cleanly mode of warming rooms; and if the gas-heating stove be properly attended to, by no means an expensive one. It is particularly applicable to churches and chapels, to counting-houses, shops, and all those places where the dust from a coal fire is objectionable.

Coal-gas has also been used to some extent for the purpose of cooking by means of the gas-cooking apparatus, which is in arrangement nearly similar to the gas-heating stove, except that it is not furnished with the internal cone. The gas-cooking apparatus, as well as the gas-heating stove, are manufactured by Mr. Charles Rickets, of 5, Agar-street, Strand, London, and also by several other gas-apparatus manufacturers in town as well as in the country.

Coal-gas cannot be manufactured, by means of the apparatus at present known, with economy, on a small scale, as, for instance, where but three or four lights are wanted; it is in the large way only that the manufacture thereof can be profitable. For the lighting of towns and large manufactories, it is most advantageously employed, but in the former case, were the street-lamps only lighted, it would yield but little profit to the manufacturer, to answer whose views many shops and interiors of public and private buildings ought to be supplied therewith

from the same range of main pipe as feeds the street-lamps. The price of coals can exert but little influence upon the price of the gas produced from them, for where coals are plentiful, it follows that they will be cheap, and hence also will be the coke produced therefrom ; but where coals are dear, the coke will also sell for a higher price and find a more ready market.

## CHAPTER XVIII.

On the Gas-Regenerators, and other Apparatus devised for most effectually converting into carburetted-hydrogen gas the Tar and Ammonia produced from the coal in the retort, as they, in a state of vapour, are on their passage to the Hydraulic Main.

IT has for many years been well known to the gas-manufacturer that carburetted-hydrogen gas can be obtained by the decomposition of liquid coal-tar by heat; but no apparatus has as yet been constructed sufficiently simple and effective profitably to effect that object. Many years ago, I was induced to adopt a modification of the present gas-generating apparatus, designed to cause light gas to be evolved from the vapour of tar and ammonia remaining suspended in the gas after it had passed through the hydraulic main, which project was at that time thought likely to succeed in practice, but nevertheless on trial was found useless, and consequently abandoned. The old beaten routine of gas manufacture in the generating department to all appearances continued everywhere to be persevered in up to the year 1830, when Mr. James Down, of Leicester, took out a patent for improvements in making gas for illumination, the specification and drawings of which may be seen in "Newton's

London Journal" (second series) for June, 1831, No. 39, page 131. The method he proposed was, that the gas obtained from two common retorts should be made to pass through a vessel containing ignited carbonaceous matter placed above them, and heated by the same furnace, prior to its reaching the hydraulic main. This vessel was divided into a number of vertical compartments, which were filled with charcoal or coke by means of movable lids on their tops, which charcoal or coke became red hot, and whilst so the gas had to force its way through it. The patentee says, "I claim as my invention, first, making or generating gas for the purposes of illumination by passing crude or nascent gas through a long stratum of ignited charcoal or coke, whereby I evolve an additional quantity of gas from certain portions of the residuum, which, in the modes hitherto adopted, are useless for those purposes; and whereby I do away with the necessity of a separate purifying apparatus: and, secondly, the improved box or vessel contrived to obtain that object by means of the extended stratum of charcoal or coke hereinbefore described." We never saw Mr. Down's apparatus in operation, nor are we aware of its having been used elsewhere than at Leicester; and from our own experience in the manufacture of gas, we are led to give it as our opinion, that the gas thence evolved must have been very deficient in purity and illuminating power, and the vessel into

which the charcoal or coke was introduced must have been found exceedingly troublesome, particularly if as described in the specification and drawings thereunto attached, setting aside difficulties which must inevitably arise by working more than one retort into it, particularly at the times when the retorts had to be drawn or charged.

For the next improvement which has fallen under our notice, a patent was taken out by Mr. John Malam, of Hull, in June, 1835, the specification and descriptive figures of which are given in "Newton's London Journal," (conjoined series,) No. 50, for May, 1836, at page 137. In the specification, Mr. Malam states, that "the improvements in the apparatus for generating gas for illumination consist in an addition to the retort commonly in use for the purpose of effecting a more perfect decomposition of the vapour arising from the coal in the process of distillation, and rendering that part which would otherwise be condensable into tar and ammonia into a permanent elastic gas, thereby greatly increasing its quantity and rendering the gas more pure and of a better quality. Retorts," he adds, "of the ordinary construction, with my improvements, may be worked at a much lower temperature than usual, as that portion of the vapour which passes off from the first process of distillation is perfected by the second, and thus the durability of the retort is considerably increased: which advan-

tages are obtained from the ordinary quantity of coal and at no additional labour or expense in the mode of heating or working." As our attention has been particularly called to this invention, and as we have now had the results of the gas-regenerator (such is the designation Mr. Malam gives to his invention) constantly before us for a period of upwards of eighteen months, verifying to the fullest extent the remark made by us when alluding to this patent in the preceding chapter at page 407, we furnish a plate of the gas-regenerators, which we shall in the first place describe, and after having done so, transcribe, for our reader's consideration, the results obtained by their use, carefully noted by us and others at those places where we have had them in operation.

*Plate XXI., figure 1*, represents a front elevation of three elliptical retorts, (the retorts may be of any shape but the elliptical, large D or kidney-shaped answer best,) with their "regenerators" and conducting pipes. *Figure 2* is a sectional elevation of the furnace, retorts, and regenerators with their flues; and *figure 3* is a longitudinal section of the same; *a, a, a* being the mouth of the retorts through which they are charged with coal; *b, b, b*, the connecting pipes through which the gas and vapour produced by the distillation in the retorts ascend to the regenerators; *c, c, c* are the mouth-pieces of the regenerators; and *d, d, d* are the ascending

pipes from which the gas passes to the hydraulic main *e*, and from thence it is conveyed to the condenser, purifiers, and gas-holder in the ordinary manner. It will be seen that the regenerators are fixed above the retorts, supported by an arch, with openings *f, f, f, f, f, f, f* left for the purpose of transmitting the heat to them more readily, but not intended for the passage or draught of flame. The heat passes from the furnace *g g*, circulating under the two lower retorts and through the openings *h, h, h, h, h, h* to the upper retort, above which it operates upon the regenerators through the openings marked *f* above described; after which the current of flame passes through the flues at the extremity of the furnace as seen at *i, i, i*, better shown in the horizontal section figure 4, and vertical section figure 5, and from thence over the regenerators to the main flue or chimney *k*, as will be seen by the direction of the arrows. It will be perceived, by reference to the longitudinal section figure 3, that the coal under distillation in the retort is discharging its gas and vapour through the connecting pipe *b*, to the regenerator, which is furnished with an internal cylinder *l l*, (through which the gas and vapour percolate,) left somewhat shorter than the external cylinder, that the gas and vapour may pass out at its extremity into the body of the regenerator, and be also adequately submitted to the action of the heat therein. It will be seen that the internal

cylinder has a mouth-piece *m*, separated from that of the regenerator for the purposes of adjusting it over the opening of the connecting pipe *b*, and cleaning it from any deposit; and the cylinder may be removed altogether at pleasure, and a fresh one substituted without disturbing the regenerators, that it may be more readily and effectually cleansed. After the gas, with the vapours suspended therein, has been submitted to the action of the heated internal surfaces of the regenerators, it passes off increased in volume and in a more pure and perfect state, through the ascending pipes *d, d, d*, to the hydraulic main *e*, as will be clearly seen in the figures. For the better illustration of the regenerator with its internal cylinder and connecting pipes, we have shown, at figures 6 and 7, the front or mouth end upon a larger scale; and the same letters of reference point out the parts corresponding to those shown in the above-named figures. *Figure 5* is a section of three regenerators of a D shape. *Figure 8*, front view of the lid for the internal cylinder of the regenerator, of which a section is shown at *m*, figure 7. It is to be noticed, that the retorts and regenerators may be of different forms from those we have described, and they may be set differently, and with a different internal arrangement in the regenerator; but in this *improved* process, each retort is provided with a separate regenerator, which is heated by the same furnace as

the retort, and this may be effected in various ways, the one shown in the plate being merely for the purpose of illustration.

In consequence of our having been for several years almost constantly absent from England, our attention was not called to the regenerators till the autumn of 1839, since which time they have had our almost undivided attention ; and the more we have seen of their operation, so much the more we are prepared to pronounce our decided opinion in their favour. In order that the reader may know upon what such an opinion is founded, we observe, that having learnt the regenerators had been used at the Wisbeach gas-works from the time that the patent had been taken out, we were invited to go down thither in November, 1839, where we found twelve elliptical retorts, each furnished with its regenerator, in precisely the same way as shown in Plate XXI. The manager of the Wisbeach gas-works was then using Whitton Park coal for making gas ; and, with his assistance, we pursued a course of experiments for a week, measuring the gas produced during the day-charges, which were weighed to the retorts by noticing the rise of the gas-holder, and making the necessary allowances for the change of temperature ; there not being then any station-meter at the Wisbeach gas-works. The results of these experiments showed that during the time they were carried on by the aid of the regenerators (the

retorts were each charged with 160 pounds of coals, and worked off at eight hours' charges), one ton of Whitton Park coal produced from between 11,500 to 12,000 cubic feet of gas. Only *one-third* of the quantity of tar and ammonia usually produced by the distillation of coal in simple retort, was found in the tar-well in these experiments. After having ascertained so much, we proceeded to the Peterborough gas-works, where the same description of coals were used (part of the same cargo as had been delivered at Wisbeach, and upon which the trial had been made there), precisely the same description of retorts, and similarly set, but without the regenerators. We pursued our experiments there, and found that from the same description of coals, and retorts worked at similar heats, the average quantity of gas procured from one ton of Whitton Park coal was between 8,500 and 9,000 cubic feet. Up to February, 1840, we had frequent reports of the operations at Wisbeach; all of which corroborated our own experiments. In that month we went to Wisbeach again, had a station-meter fixed, and made some trifling alterations in the internal arrangement of the regenerator; having done which, we continued our experiments up to the end of March, and found that we obtained as much as 12,338 cubic feet from a ton of Butterknowl coals. From that time up to the present, the reports made to us, from time to time, by the manager of the

Wisbeach gas-works, show similar results. In the summer of 1840 we erected a small gas apparatus at a manufactory near London, where we put up two elliptical retorts and two regenerators. This apparatus was brought into action in November, 1840, and for some time was worked under our own immediate control and inspection. From notes made by us at the time, we make the following extracts, beginning with the first day's experiment, and repeating such regularly for seven successive days: the coal used was Townley Main; and the retorts were charged with 160 pounds thereof at one time:—

1st day,	12,815	cubic feet of gas to the ton.
2nd „	12,903	ditto ditto.
3rd „	„	quantity of gas not ascertained.
4th „	„	retort not worked.
5th „	12,935	cubic feet of gas to the ton.
6th „	12,193	ditto ditto.
7th „	12,715	ditto ditto.

Showing an average produce of something more than 12,500 cubic feet of coal-gas, of the very best quality, from one ton of coals. The specific gravity of the gas so obtained, taken with great care, and bringing into account the temperature, as well as the barometric pressure, averaged  $\cdot 569$ . The retorts were set singly (each with its regenerator) over a coke-oven, which, when heated to a proper tempera-

ture, produced an exceedingly good coke. Taking, however, all things into consideration, we are not of opinion that coke-ovens are so eligible for heating retorts as furnaces, where the gas-regenerators are used.

From the results at Wisbeach, and at the Hull gas-works, and from the attention we have paid to the gas-regenerators, we are of opinion that their adoption holds out to the gas manufacturer the following advantages:—They will diminish the expenditure of coals for making gas full twenty-five per cent., and that of fuel for heating the retorts to the same amount. The expenses of labour, except in very small gas-works, will be reduced to the same extent, as will also the wear and tear of retorts, grate-bars, and furnaces. The quantity of gas generated from a given quantity of coal will be augmented at the minimum full twenty-five per cent., but in many cases the increase of volume thereof will amount from thirty-three to forty-one per cent. The specific gravity of the gas will also be increased fully twenty per cent., so that, summing up the above advantages, it may be fairly estimated that such gas companies as may adopt the use of Mr. Malam's patent regenerators will save thereby upon their operations full thirty per cent., after making ample allowance, in the way of interest, for the capital sunk in the first erection of regenerators, for their wear and tear, and purchasing or

renting the patent right. We apprehend we need not say any more as to the advantages which the regenerators hold out in a pecuniary point of view, as every one interested in a gas manufactory can very easily calculate for himself what savings would by their use be annually effected, by comparing the cost of coals (less what may be received for coke) on a system by which 9,000 cubic feet of gas from a ton of coals is the *maximum* obtained, with the cost when 12,000 cubic feet of gas are obtained from a ton, the fewer retorts he would have to work in the latter case, and the consequent saving in fuel, wear and tear of retorts and grate-bars, lime, and labour.

That the subject of causing the gas in its crude state to undergo a second distillation prior to its being permitted to enter into the hydraulic main, for the purpose of converting the many vaporous particles of tar and ammonia with which it was charged when it left the retort, into gas, has been considered worthy the notice of scientific and practical men, appears evident from the attention lately paid thereto by many eminent chemists, English and foreign, and from more than one patent having been taken out since Mr. Malam took out his patent for the regenerators, for producing results somewhat resembling those which he obtains, and in which, though the apparatus be dissimilar in appearance, still several of the more recent inventions are but

imperfect modifications of his perfect method. The first that we shall notice was patented in February, 1838, by the Marquis Montauban (see "Newton's London Journal," conjoined series, No. 82, for January, 1839, page 185). He proposed to use an additional distillatory vessel which he called a decomposer, to a nest of four or a greater number of retorts, which vessel he proposed to fill with iron tubes or plates, so as to afford a large heated surface for the gas to pass over before it reached the hydraulic main. When four retorts were set in one nest, the gas from each of them was received into an iron cylinder, and from that the gas generated by the whole number was conveyed to the decomposer, entering at one end thereof, and making its exit at the other towards the hydraulic main. For the reasons we named when speaking of the use of the hydraulic main, a difficulty arose in consequence of so many retorts working into one common cylinder, which could not be got over without placing cocks or valves upon each of the ascending pipes, so that when one of the retorts had to be drawn and recharged, its communication with the said common cylinder might be shut off. Such cocks or valves were therefore provided ; but looking at the situation in which they were placed, most persons practically acquainted with the operations of a gas-light manufactory would at once see that their being kept in such a state as always to work quite freely

(a thing of very great importance, both as regards the isolating a retort, as well as again connecting it to the common cylinder) and to remain perfectly gas tight, were things by no such means to be easily effected.

The second originated with Mr. George Lowe, engineer, who used double retorts set end to end in the same brick-work, so that together they were of about twice the length of those generally used. Each had its separate mouth-piece, and hydraulic main, and from the hydraulic main each could be shut off at pleasure. The ends of these retorts were connected together by means of a cast-iron pipe, so that there was a communication between the two. The mode of operation was as follows: the retorts having attained a proper heat, one of them was charged, and the connexion between it and the pipe attached to its mouth-piece which led towards the hydraulic main was shut off by means of a valve; in consequence, the gas as it was generated passed through the uncharged retort, and by the pipe attached to its mouth-piece entered the hydraulic main when the first charge was thought to be about half burnt off, the lid of the uncharged retort was removed, and that retort was charged when the valve between the hydraulic main and the first-charged retort was opened, and the similar valve to the second-charged retort closed; in consequence, the gas making therein had to pass over the red-hot coke

in the first-charged retort, on its way to the hydraulic main; and thus the two retorts were continued to be charged alternately. We need not make any remarks here about the valves, but it is evident that from the time the lid of one retort was removed till the charge was drawn, the retort recharged, and the lid reluted and secured, the gas making in the other must escape through it. To remedy this evil, as the specification states, a patent was taken out in December, 1839, by Mr. Lowe, and Mr. John Kirkham, engineers, jointly, for a mode of combining and working retorts in the manufacture of gas from coal, and in such a manner that the products alternately of one of two retorts shall be caused to pass into and mix with the products of the other retort, by which means, whichever of the two retorts has been last charged, the products thereof, during the early hours of working, shall pass into the retort which, with its charge, is in a highly heated state, from its having been much longer at work; and the retorts are so connected by means of a valve and apparatus external of the brick-work of the setting of the retorts, that during the time of discharging and charging either of the retorts, the gas from the other retort shall not pass into the retort with which it is connected, and which is long discharged of its contents or recharged with coal. The times and modes of drawing the retorts are nearly similar to what we have already mentioned when speaking of Mr. Lowe's

double retort ; the principal difference that we perceive between one mode and the other is, that the two retorts are connected together at the back and outside the brick-work by a pipe, whereon is placed a slide valve for the purpose of shutting off the connexion between the two during the process of drawing and charging either. The reader who may feel desirous of obtaining further information relative to this patent, which embraces several other matters, such as upright retorts, intended to produce similar results to those we have spoken of, the using of clay retorts, the employing of coal-tar as fuel, &c. &c., will find the specification, with figures of reference in Number 82 (new series) of the "Repertory of Patent Inventions" for October, 1840, page 193.

Having now noticed the inventions which appear most likely to produce somewhat similar results to what are effected by Mr. Malam's patent gas-regenerators, we shall very briefly notice the points in which we think one has, both in theory and practice, a most decided superiority over the other : meanwhile again observing, that several of the patents taken out subsequently to his are but mere modifications of his method, and those by no means for the better, as the scientific and practical reader will readily perceive on comparing the several apparatus. The gas-regenerators require no valves, the others cannot be worked without them ; and we are of opinion that it will always be found in practice, that the more

simple the construction of a machine is, so much the more valuable it is. Valves fit for the purpose intended are expensive in the first instance, and very liable to become deranged. In very large establishments, however, where there are plenty of workmen, the use of valves for such purposes as are intended in the patents we have alluded to is not so objectionable as in small works (supposing they do not get clogged with tar, and can be kept gas tight); but we cannot fail to give it as our opinion, that they are to a certain extent objectionable in all; therefore, supposing the same volume of gas to be produced by one method as by another, we think the patent gas-regenerators are to be preferred, being simple, self-acting, and not liable to get out of order. But even if we could admit the volume of gas procured to be similar in all cases, we are not at all prepared to allow that the increase in volume, obtained by passing the crude gas over so highly heated a material as must be the interior of a retort when to a certain extent filled with red-hot coke, is by any means allied to so great a specific gravity as that which is obtained by passing such gas through a vessel heated to such an extent *only* as is sufficient for arresting the vapours of tar and ammonia, and converting them into such a valuable gas, with an increase of illuminating power as well as of volume, as can be produced by the regenerators. It being well known that the illuminating power of well-pu-

rified coal-gas is increased as its specific gravity or the proportion of carbon therein increases, it follows that such gas will go further, and be of more value. The regenerators once fixed, and their lids secured, require no attention or attendance for weeks together; and when it may be necessary to examine their interior, it can be done when the retort to which each is attached is drawn, and will not occupy more time than would be necessary for drawing and recharging a retort. Practice has however most satisfactorily shown, that the internal pipes in the regenerators do not begin to get foul until a very long period has passed, so that in most cases months may elapse without its being necessary to examine their interior. The regenerators, once properly fixed in their places, will also last in the most effective state as long as three or four sets at least of the retorts set under them, a fact which experience has fully demonstrated, as they can also be replaced with very little trouble and expense.

NOTE.—All persons desirous of further information concerning the gas-regenerators, may obtain all particulars relating to them, by an application (post-paid) at the author's address in London, 10, Arundel-street, Strand.

## CHAPTER XIX.

On the Method of ascertaining the Specific Gravity of Coal-Gas.

IT being universally admitted that the illuminating power of well-purified coal-gas increases very much with the increase of its specific gravity, and that that entirely depends upon the increased proportion of carbon present in its constitution, we propose to dedicate a page or two to the description of the method we have adopted for experimentally ascertaining the specific gravity of coal-gas, or any other gas. In the first place, we have provided ourselves with a very nicely adjusted scale-beam, upright standard, one scale, and a copper flask, containing  $61\frac{1}{2}$  cubic inches, with weights to exactly counterpoise the flask when filled with common air, and its appurtenances, when they are attached by a hook to one end of the scale-beam. We have also an exhausting syringe, and a set of grain and smaller weights; and, in making our experiments, we make use both of a barometer and a thermometer. We first note the temperature and barometric pressure of the atmosphere, and having so done, the pieces (see

figures 3, 4, and 4\*) are connected together and screwed to the flask in the order in which they are placed in Plate I., by uniting the cock (figure 3) to the flask by means of the screw *c*; to the screw *b* at the other end of the cock we attach the piece, figure 4, which is fitted with a valve made of goldbeater's skin at *a*, over which we screw the piece, figure 4\*, fitted with a hook *d*, as shown. Things being so far prepared, before we proceed further we calculate what  $61\frac{1}{2}$  cubic inches of atmospheric air, at the temperature and barometric pressure then noted, weigh; preparatory to doing which, we find what  $61\frac{1}{2}$  cubic inches (or any other content in cubic inches of which a flask may be constructed) weigh; and as it is known that when the barometric pressure is 30 inches, and the temperature 60 degrees, 100 cubic inches of air weigh  $30\frac{1}{2}$  grains, we proceed, first, to find what  $61\frac{1}{2}$  cubic inches of air would weigh under like circumstances, and say

Cubic inches.	Cubic inches.	Grains.	Grains.
as 100	: 61.5	:: 30.5	: 18.7575;

this found, we put *D* for density, and pressure  
 $= kD(1 + at^{\circ}) = kD\left(1 + \frac{.025}{12}t^{\circ}\right)$ ; for, the expansion  
of the air between the freezing and boiling points  
 $= .375$ , consequently, that for one degree Fahrenheit  
 $\text{heit} = \frac{.375}{180} = \frac{.025}{12}$ .

To find *k* being constant, we have

$$\begin{aligned}
30 &= k \, 18.7575 \left( 1 + \frac{.025}{12} t^{\circ} \right) \\
&= k \, 18.7575 \left( 1 + \frac{.025}{12} 28 \right) = 1.0583 \\
&= k \, 18.7575 \left( \frac{3.175}{3} \right) = k \, 6.2525 \cdot 3.175 \\
1 &= k \cdot 2084 \cdot 3.175 = k \cdot 66167 \\
\therefore p &= \frac{D}{.66167} \left( 1 + \frac{.025}{12} t^{\circ} - 32^{\circ} \right) \\
\therefore D &= \frac{p \cdot 66167}{1 + \frac{.025}{12} \cdot t^{\circ} - 32}
\end{aligned}$$

The above is a formula by which D, or density, is found, if  $p$  pressure, and  $t^{\circ}$  temperature in degrees Fahrenheit be given. Supposing the flask to contain  $61\frac{1}{2}$  cubic inches, the barometric pressure to be 28 inches, and the temperature 45 degrees, we will have 18.03 grains as the result; which we show thus :—

$$\text{Example. } D = 28 \cdot \frac{.66167}{1 + \frac{.025}{12} \cdot 45^{\circ} - 32^{\circ}} = 18.03$$

$$\text{for } 1 + \frac{.025}{12} \cdot 13 = 1 + \frac{.325}{12} = 1.027$$

$$\text{then, } \frac{.66167 \times 28}{1.027} = 18.0396884.$$

The same calculation will give just results in all other cases, be the barometric pressure and tempera-

ure what they may, if we substitute for  $p$  the actual barometric pressure, and for  $t^\circ$  the temperature in degrees of Fahrenheit.

We attach the flask and its appendages to one end of the scale-beam by the hook  $d$ , figure 4\*, and by weights put into the scale at the other end of the beam, we very exactly balance it. We then remove the flask from the scale-beam, unscrew the piece, figure 4\*, and screw on the exhausting syringe upon the piece, figure 4, at  $a$ , and proceed to exhaust the flask, which, when we have accomplished, we shut the stop-cock. To know when the most perfect vacuum possible has been formed, after removing the exhausting syringe, we screw on the piece, figure 4\*, and again attach the flask to the scale-beam; then, if the most complete rarefaction has taken place, very nearly as many grain weights will be required to be laid upon the thumb-piece of the cock of the exhausted flask, as we found by our calculation its contents of atmospheric air, at the then temperature and barometric pressure, weigh, to bring the scale and flask ends of the beam into equilibrium. We again detach the flask from the scale-beam, keeping the stop-cock shut, and remove the pieces, figures 4 and 4\*, and then attach the flask, by means of the screw  $b$ , to a union joint upon the pipe, containing the gas of which we want to know the specific gravity; between which union joint and the gas pipe there is fixed a stop-cock.

We then open the last-named cock, and afterwards the cock attached to the exhausted flask; upon which the gas rushes into, and in a few seconds fills it from the pipe. We then shut both cocks, and unconnect the flask and its cock from the union joint, attach thereto the pieces, figures 4 and 4\*, and again hook it on to the scale-beam, as before; we then place grain (or smaller) weights upon the thumb-piece of the cock attached to the flask, till the weight in the scale at the opposite end of the beam is exactly counterpoised; we then subtract this last-ascertained weight from the weight of air which was necessary to fill the flask when the experiment was made; the difference, it is evident, must be the weight of the gas then contained in the flask: we therefore say,

As the weight of the atmospheric air necessary to fill the flask in grains, &c.

Is to the weight of the gas contained therein also in grains, &c.,

So is 1000, the specific gravity of air,

To the specific gravity of the gas under trial.

For example, we found that the barometric pressure was 30·52 inches, that the thermometer stood at 46°, and that, after proceeding as above, we also found it required  $8\frac{1}{2}$  grains to counterpoise the weight in the scale when the flask was filled with gas: we first find, by the method already mentioned, that 61·5 cubic inches of air, the barometer

standing at 30·52, and the thermometer at 46°,  
 weigh . . . . . 19·66 grains;  
 from which we take the counterbalance 8·50 „

the remainder . 11·16 grains,

is the weight of 61·5 cubic inches of the gas under  
 trial :—we then say,

Grains.	Grains.	Specific Gravity.	Specific Gravity.
As 19·66	: 11·16	:: 1000	: ·567,

the specific gravity sought, being that of the coal-gas produced by the addition of gas-regenerators to elliptical retorts working at a cherry-red heat.

## CHAPTER XX.

Description of the Gas-Works at Bury St. Edmunds, given for the purpose of showing the general arrangement of a Gas-Light Manufactory.

As we have heard it frequently remarked, that there is not a published plan of any existing gas-work, and that it is very desirable such a plan should be laid before the public, we take this opportunity of furnishing a ground-plan, front, back, and side elevation, and a vertical section of one recently built at Bury St. Edmunds, all drawn from a scale of one-sixteenth of an inch to a foot, which we propose to describe. We remark, that similar letters of reference are placed against corresponding parts of the manufactory in the Plates II., III., IV., V., and VI.

*Plate II.* represents a front elevation of the gas-works, in which A A is the dwelling-house of the superintendent or foreman, consisting of a parlour, 20 ft.  $\times$  15 ft. 9 in., with two bed-rooms over it, and a kitchen, 16 ft.  $\times$  11 ft. 6 in. B is the office, 16 ft.  $\times$  11 ft. 6 in. The fire-places in the office and in the foreman's house have descending flues which lead into the chimney G (Plate VI.).

C is the retort-house and coal-store, one-half of which is employed as a coal-store, the other for the retorts, being roomy enough for the labour therein required. This building is 50 ft.  $\times$  42 ft. inside, and height to wall-plate 16 ft. D is a work-shop fitted up with vice-bench, tools, &c., and is of the same dimensions as the office; height to wall-plate 10 ft. 6 in. E is a store-room for keeping and slaking the lime for purifying the gas; it is of the same dimensions on the plan as the foreman's kitchen; height to wall-plate 10 ft 6 in. F is the house for the purifiers, 20 ft.  $\times$  20 ft. inside (all the dimensions given are inside ones on the plan); height to the wall-plate 16 ft. The chimney is a column 70 ft. in height, inclusive of the cast-iron vase at the top, which is 5 ft. diameter at its widest part and 4 ft. in height. The whole of this front, as well as the side and back elevations and the chimney, is built of brick, finished partly with Portland-cement and partly with stone for coping, mouldings, &c. &c.

*Plate III.* is a vertical section of the works, in which a front elevation of the retorts and elevations of the purifying apparatus and valve are shown: the other parts, having the same letters of reference as corresponding parts in Plate II., do not require to be referred to.

*Plate IV.* exhibits a back elevation of the foreman's dwelling-house, the office, the retort-house,

and coke-store, the work-shop and the house for the purifier already sufficiently described. It also shows a front elevation of the coke-store, drawn from a scale of one-eighth inch to a foot, the wall-plate in front of which is supported by four cast-iron columns and two half columns, each 8 ft. in height. Four cast-iron plates are placed between the columns as shown, for the purpose of keeping up the coke; these are each about 3 ft. 9 in. in height by 8 ft. 6 in. in length, and  $\frac{1}{2}$  inch thick, and cast with mouldings as shown. The internal dimensions of the coke-store on the plan is 48 ft.  $\times$  10 ft.

*Plate V.* exhibits a side elevation of the foreman's dwelling-house and the retort-house: the doors to the latter are folding, and made of cast-iron, the louvering shown in the openings are of plate-iron. O represents one of the gas-holders nearly full of gas, it is supported from four points at the circumference by the cast-iron columns *a, a*, described at pages 305, 309, where figure 4, *Plate XV.*, is explained. *b*, the back boundary wall, supported by strong buttresses of brick-work, to sustain the pressure upon its back of the ground, that being about thirteen feet higher than the level of the ground upon which the works are built.

*Plate VI.* is a ground-plan of the works which, as far as relates to the office, the foreman's dwelling, the retort-house, and coal-store, the vice-room, lime-store, and house for purifier, requires no further

description. On this plan, however, it may be noticed, that not only the flue from the bed of retorts, but also the flues from the fire-places in the office and foreman's dwelling-house are carried underneath the floor of the retort-house and coal-store, into the base of the chimney marked G. The base of the chimney is divided into two parts by a nine-inch brick-wall, as shown, to a height of about three feet above the points at which the respective flues enter, a precaution very necessary to be taken to prevent the draught being checked by interfering flues, as we have sometimes witnessed. When flues meet, or act against each other, no dependence whatever can be placed upon the draught ; for first one will fail and then another, according to the quarter whence the wind may blow. The pipe shown as leading from the purifying-house towards the chimney is for carrying off the vapour from the impure lime, either whilst it remains in the purifying vessel through an aperture in the lid, which is opened after it is thrown out of action, or, as has already been described at page 246, from a receptacle made for it after it is removed from the purifier, and having a draught hole through it. HH is the plan of a bed of eighteen elliptical retorts, dimensions twenty inches by ten inches inside ; length, exclusive of mouth-piece, six feet six inches. These are set on precisely the same plan as the three large D retorts, shown in figures 5, 6, 7, 8, 9 and 10, Plate VIII.,

and described at pages 146—148 preceding. \* \* represents the situation of the hydraulic main. *a* is the pipe for conveying the tar and ammoniacal liquor to the tar-cistern *J*, upon which is a branch leading towards the washer *I*, which conveys into that vessel the gas and such portions of tar and ammoniacal liquor as may, after it leaves the hydraulic main, remain in a state of vapour. *I* is the washer, similar to the one shown by figures 9 and 10, Plate XI., and described at pages 217 and 218. *J* is the tar-well, similar to the one shown at figure 9, Plate XII., and described at page 227. *c* is a four-inch pipe leading from the washer to the condenser, upon which is an outlet for conveying any tar and ammoniacal liquor produced by further condensation in the washer and condenser *K K K*, by the pipe *b* into the tar-well. The pipe *b*, and also the pipe *a*, have each a dip-pipe for receiving them in the tar-well, as described at page 227, where the tar-cistern, shown at figure 3, Plate XII., is explained. *K K K* represents the condenser, which is fixed in an oblong tank made of masonry, the top of which rises about six inches above the ground level of the works, and is finished with a coping of three-inch Yorkshire flagging. The inside dimensions of this tank are eighteen feet by nine feet, depth about three feet. It is built of brick, laid in Roman-cement, with a coat of Roman cement inside the upright walls, of

about one inch in thickness ; the bottom, except where the boxes we are about to mention are placed, is well puddled, as are also the backs of the walls, in the way already shown in our description of brick-tanks for the gas-holders to work in. The condenser consists of four rectangular cast-iron boxes, each about eight feet six inches in length, one foot in width, and two feet in depth, cast with sockets upon their sides for receiving four-inch cast-iron pipes. The boxes are cast with partitions in them, somewhat similar to that at the bottom of the condenser, shown at figure 3, Plate XI. The pipes being jointed to these boxes, it is evident that if the gas enters the condenser by the pipe *c*, it will be compelled (there being but one pipe in the first box communicating with that pipe, the partition in the box shutting off all others) to proceed to the opposite end of the condenser, where the partition in the box there includes two pipes, and allows it to return by the second pipe to the end at which it first entered, and so on alternately from end to end, by means of partitions in the end boxes, each including two pipes, except the first and last (in the other two boxes the partition-plates are placed between each pipe of the range of which the condenser is formed), till it comes to the single division in the box communicating with the pipe *d*, which conveys the refrigerated gas towards the purifier. The

boxes are placed upon piers of brick-work of different heights, and so that the box at the entrance and exit end is about six inches lower than that at the opposite end; consequently the pipes have a regular fall of about six inches in the entire length, and thereby cause the condensable products to fall into the lowest box, and be thence conveyed by the pipe *b* to the tar-cistern J. L 1, L 2, L 3, and L 4 are the dry-lime purifiers, of very nearly the same construction as the purifier shown at figure 1, 2, and 3, Plate XIV., and described at pages 247—259; the principal difference is in the internal cylinder, or lifting part of the valve M, which is constructed with the partitions in the reverse order, which of course reverses the order in which the purifiers are thrown out of action, so that the centre valve, shown at figure 2, Plate XIV., represents figure 4 there shown, and *vice versâ*. Plate XIV. represents the action as from right to left; here L 1, L 2, &c., show it is from left to right. *e* is a four-inch pipe for conveying the purified gas to the gas-holders N and O, the inlet and outlet pipes of which *e* and *f*, and *e* and *g*, and also the gas-holders, valves attached to them, and the pipe *g g*, and *f* leading to the governor P have all been fully explained, along with figure 4, Plate XV., at pages 305—309. P is the governor, shown at figures 10, 11, 12, and 13, Plate XXII., and described at pages 389—393.

Q Q is a plan of the coke-store, the dimensions of which were given when describing its front elevation. R and S are the privies. *h* a five-inch main pipe for conveying the gas from the governor to the street-mains, the leading one of which is of that diameter.

Having now given very lengthened and full descriptions of every part of the apparatus used in the gas manufactory from the retort to the governor, and also furnished detailed plans, &c., of a gas-work now in actual existence, we have little more to add beyond observing, that the arrangement of a gas-manufactory must always depend very much upon the plan of the ground it has to be built upon. In our practice we have had plans of almost all shapes to erect works upon—some very irregular ; but when uniformity of arrangement is considered, the ground-plan of the works ought to be always rectangular. In choosing a site for a gas manufactory, it will always be well to recollect that a low situation is preferable to one more elevated, because, from the levity of the gas, its passage through the pipes will be effected with less pressure. Such a situation, near a river or canal from which the coals required are delivered, is very desirable, as thence will arise a great saving in the expense of carriage of that article. We may remark that, in several instances, we have placed the purifiers in a room over the

lime-store, which we find very convenient in practice; for, under such an arrangement, the entire of their bottoms, and the various pipes connected therewith, are easily accessible. We also recommend that the gas-holders, on all occasions, should be fixed in the open air (and not have houses built round them, or be covered in, as is the case in some places), as the least expensive and decidedly the safest method. An arrangement similar to that given in Plate VI. presents a uniformity of appearance, and saves room. However, the arrangement of the apparatus must vary with local circumstances, and therefore no general rule can be given for the purpose. It will be obvious, notwithstanding, that it will always be well to place the gas-holders at as great a distance from the retort-house as the premises will allow.

After what we have said, we expect there is now no occasion to recapitulate the different parts of the apparatus, or to point out how and where the gas is first produced in the manufactory, or how it passes from the washer to the condenser, from the condenser to the purifier, and thence to gas-holders, &c., ready for supplying the demand. And having, for the third time, led the reader through the different stages of the process for generating, collecting, and distributing coal-gas, and, we hope, introduced to his notice such plans, &c., as are at the present period most worthy of his consideration, we

again take our leave, with a firm conviction that, though much has been achieved tending to promote the progress of gas-lighting, still there is a wide field open for improving and simplifying that apparatus by means of which coal-gas is *now* obtained.

THE END.

# I N D E X.

---

## A.

	Page
<i>Air</i> , a proper supply of, necessary for supporting combustion	6
<i>Ammoniacal Liquor</i> , quantity of, produced from a ton of coals . . . . .	224
<i>Argand Gas-Burner</i> , whence the idea of it arose . . .	35
<i>Argand Lamp</i> , how the idea of it was first suggested. .	6
„ advantages attending the use of . . .	6
<i>Artificial Light</i> , how produced at the least expense . .	5

## B.

<i>Bend-Pipe</i> , description and use of . . . . .	341
<i>Bend-Pipes</i> , wrought-iron, where used . . . . .	351
<i>Branch Pipe</i> , description and use of . . . . .	340
<i>Brande, Mr. T. W.</i> , obtains carburetted-hydrogen gas from coal, from the dried wood of the common willow, from white birch-wood, from hazel-wood, and from writing-paper . . . . .	411
<i>Brass-Cross</i> , description and use of . . . . .	357
<i>Brass T-Piece</i> , description and use of . . . . .	358
<i>Burners, Gas</i> , best size for obtaining a large quantity of light	25
„ Argand more economical than single jets . . .	25
„ fifteen-hole, consumption of gas per hour . . .	28
„ ditto mould candles equal to . . . . .	28
„ Argand should always be used with glass chimneys . . . . .	36
<i>Bury St. Edmunds Gas-Works</i> , description of . . . .	441

## C.

<i>Candle-Light</i> , reading by, why injurious to the eyes . .	7
„ how to obviate its variability as suggested by Mr. Ezekiel Walker . . . . .	7
<i>Candle</i> , for what purpose the wick is used . . . . .	12

	Page
<i>Candle</i> , wick of, why it becomes black . . . . .	13
„ whence smoke from it is produced . . . . .	14
„ with a wick of a single thread, effect of . . . . .	15
„ remarks on the thickness of the wick of . . . . .	15
„ wick of a wax one may be made much slighter than that for tallow, and why . . . . .	15
„ with a thick wick, effects of under various circum- stances . . . . .	13
„ made of wax, its action . . . . .	16
„ „ is snuffed spontaneously . . . . .	16
„ made of tallow, what is required for making it equal to such as are made of wax . . . . .	16
„ not requiring snuffing, why advantageous . . . . .	9
<i>Candles</i> , mould and ill-snuffed dips, cost of obtaining light from respectively, compared with light afforded from wax, sperm-oil, whale or seed-oil, and coal-gas . . . . .	26—29
„ how to ascertain and compare the illuminating powers of with other luminous bodies . . . . .	17
„ on the variability of light they afford when burnt vertically . . . . .	7
„ so placed as neither to produce smoke nor require snuffing, effects of . . . . .	7
<i>Candles and Lamps</i> , theory of the action of . . . . .	11
<i>Carbonization</i> , when carried on disadvantageously . . . . .	190
„ how to be managed, so as to produce the greatest quantity of gas in the least time from equal quantities of coal . . . . .	125 and 188
<i>Carbonizing</i> , importance of the process of . . . . .	163
„ mode adopted for, in the earlier stages of the manufacture of gas . . . . .	164
„ consequences resulting from such mode . . . . .	165
„ opinion of some as to the per centage at which it might be carried on . . . . .	165
„ the per centage it has been reduced to . . . . .	175
„ best temperature for . . . . .	166
„ whence arose the idea of working short charges . . . . .	169
„ considerations relative to short charges . . . . .	172
„ why six hours' charges are not so profitable as those of eight hours' . . . . .	176

<i>Carbonizing</i> , a week's experiment stated when working six hours' charges . . . . .	176
,, a week's experiment stated when working eight hours' charges . . . . .	177
,, balance struck between the above two processes	180
,, further experiments on the eight hours' process	181
,, balance between the above process and that of six hours . . . . .	180
,, when carried on at the six hours' process disadvantages of . . . . .	181
,, annual balance in favour of the eight hours' process when working with cylindrical retorts . . .	183
,, absurdity of working short charges with cylindrical retorts . . . . .	184
,, to be carried on advantageously, the coal must be submitted in thin strata . . . . .	129
,, carried on by cylindrical or small D-retorts, set on the oven-plan, remarks upon . . . . .	173
,, when carried on by semicircular, kidney-shaped, or elliptical retorts, remarks upon . . .	175
,, coals for, recommended to be introduced into the retorts in sheet-iron trays . . . . .	186
,, a week's experiment stated when working elliptical retorts at four hours' charges . . . .	190
,, balance in favour of working elliptical retorts .	192
<i>Carburetted-Hydrogen Gas</i> , produced from pit-coal . . .	405
,, qualities of, differ with circumstances . . . . .	406
,, found ready formed on the surface of stagnant waters and in marshes . . .	407
,, how procured from charcoal . . . . .	407
,, ditto spirits of wine	408
,, may be obtained from most animal and vegetable substances . . . . .	408
,, procured from ether, or alcohol	408
,, specific gravity of . . . . .	409
,, how the greatest proportion of may be obtained in the least time . . . . .	411
,, obtained from coal-tar . . . . .	409

	Page
<i>Carburetted-Hydrogen Gas</i> , quantity obtained from a pound of coal-tar . . . . .	409
"                    obtained from wood, by Messrs. Sobolowsky and Horrer, of St. Petersburg . . . . .	411
"                    obtained from coal, oxygen required for burning . . . . .	412
"                    obtained from wax or lamp-oil, oxygen required for burning . . . . .	412
<i>Cement, Iron</i> , how made and mode of using . . . . .	339
<i>Clayton's, Dr.</i> , account of obtaining gas from pit-coal . . . . .	77
<i>Clegg, Mr. Samuel</i> , communicates to the Society of Arts his method of lighting up manufactories with gas . . . . .	91
"                    his rotary retort described . . . . .	121
"                    ditto          performance of . . . . .	122
"                    ditto          why not used . . . . .	123
"                    his revolving gas-holder described . . . . .	298
"                    his collapsing gas-holder noticed . . . . .	298
"                    his gas-meter with reciprocating motion . . . . .	361
"                    ditto          patent, with a rotary motion . . . . .	363
"                    patent governor described . . . . .	383
<i>Coal</i> , description of, and where found . . . . .	38
" varieties and composition of, viz :—jet . . . . .	38
" cannel . . . . .	39
" common and spurious . . . . .	40
" Anthracite, Kilkenny, and Culm . . . . .	41
" sulphureous and Bovey . . . . .	42
" theory of the combustion of, considered for the purpose of explaining the nature of gas-light and its production . . . . .	60
" products expelled from by the action of heat . . . . .	60
" statement of successive discoveries made in decomposing . . . . .	68
" composed of carbon, hydrogen, azote, oxygen, sulphur, hygrometric water, and earthy matter . . . . .	405
" produced from when distilled in close vessels at a heat equal to 1077° Fahrenheit . . . . .	406
<i>Coal, Pit</i> , not the only substance producing carburetted-hydrogen gas . . . . .	407
<i>Coal, Fire</i> , observations on the process of its combustion . . . . .	62

<i>Coal-Gas</i> , cost of obtaining light from, compared with cost of obtaining light from wax-candles, mould, and ill-snuffed tallow-candles, whale, seed, or sperm-oil . . . . .	26—29
„ economy of, compared with the economy of oil-gas . . . . .	106
„ how distributed for use . . . . .	61
„ heaviest obtained during the early parts of the distillatory process . . . . .	409
„ average specific gravity of . . . . .	409
„ specific gravity of, how to ascertain . . . . .	435
„ how mixed with atmospheric air so as to form an explosive compound . . . . .	413
„ smell of, a fortunate circumstance . . . . .	413
„ light afforded by, can be applied in any direction . . . . .	414
„ deprived of its smell, would render its application dangerous . . . . .	413
„ explosions from, when mixed with atmospheric air, not of frequent occurrence . . . . .	414
„ used for cooking . . . . .	416
„ used for heating churches, chapels, shops, counting-houses, warehouses, &c. . . . .	415
„ cannot be manufactured economically on a small scale . . . . .	416
„ for what purposes most advantageously used . . . . .	416
„ price of, not depending upon the price of coals . . . . .	417
<i>Coal-Gas Establishments</i> , their extent and power in London . . . . .	66
<i>Coal-Mines</i> , of Durham and Northumberland, the number of years capable of affording a supply . . . . .	57
<i>Coals</i> , classification of, as regards their uses in the gas-light manufactory . . . . .	42
„ of the first class under this arrangement, of what they consist . . . . .	43
„ of the second class, ditto ditto . . . . .	47
„ of the third class, ditto ditto . . . . .	50
„ analyzing of, considerably extended by the introduction of the manufacture of gas . . . . .	66
„ distilled in London daily for the generation of gas . . . . .	67
<i>Coal-Tar</i> , quantity of, produced from one ton of coals . . . . .	224
„ carburetted-hydrogen gas obtained from one pound of . . . . .	409

	Page
<i>Coal-Tar</i> , how proposed to be converted into gas, by the Marquis Montauban . . . . .	409
„ how proposed to be converted into gas, by the Comte de Val Marino . . . . .	410
<i>Coke</i> , the base of coal . . . . .	61
„ how made to answer the purpose of the maltster, or for metallurgical operations . . . . .	149
<i>Coke-Ovens</i> , retorts heated by means of . . . . .	137
„ for heating retorts, where beneficially used . . . . .	138
„ directions for working . . . . .	149
<i>Combustion</i> , spontaneous, whence occurring . . . . .	4
„ result of, when carried on favourably . . . . .	4
„ result of, when incomplete . . . . .	5
„ imperfect, soot a sign of . . . . .	5
<i>Condensation of Gas</i> , various modes of effecting . . . . .	207
„ by mains from retort-house to purifier . . . . .	207
„ by worm pipe in tank of gas-holder . . . . .	207
„ by parallel lines of main pipes in the works . . . . .	207
„ remarks upon the modes above mentioned . . . . .	207
„ by main pipes, why objectionable . . . . .	209
„ by the patent condenser of Mr. Perks . . . . .	210
„ by Mr. Malam's condenser . . . . .	212
<i>Condenser</i> , now generally used . . . . .	214
„ such as fixed in several places by the Author . . . . .	216
„ of plate-iron, fit for a small manufactory, described . . . . .	219
„ proper for a large gas-manufactory . . . . .	221
<i>Connecting Pieces</i> , wrought-iron, described . . . . .	351
<i>Croll, Mr. A. A.</i> , his patent for depriving coal-gas of ammonia . . . . .	262

## D.

<i>Daniel, Professor</i> , invents an apparatus for converting resin into gas . . . . .	104
<i>De Carolles, M. Blondeau</i> , proposes purifying coal-gas from ammonia therein contained . . . . .	261
<i>De Val Marino, the Comte</i> , proposed method for obtaining carburetted-hydrogen gas from coal-tar . . . . .	410

	Page
<i>Diminishing Pipes</i> , description and use of . . . .	341
<i>Dip Pipes</i> , description of section of . . . .	196
<i>Doors</i> , sliding, for furnaces, with slide, &c. . . .	151
<i>Door and Frame</i> , for furnace and ash-pit . . . .	159
<i>Double Sockets</i> , wrought-iron, where used . . . .	351
<i>Down's, Mr. James</i> , patent for improvements in making gas noticed, and mode of operation described . . . .	418

## E.

<i>Ess-Pipe</i> , description and use of . . . .	341
<i>Explosion</i> , from coal-gas, not to be expected under ordinary circumstances . . . . .	413
,, from coal-gas when mixed with atmospheric air, what combination of circumstances required to produce . . . .	413
<i>Eye</i> , human, not fitted for judging of the intensities of different lights . . . . .	17
,, particularly adapted for judging of the strength of shadows . . . . .	17

## F.

<i>Fire</i> , has been known in all ages . . . .	2
,, used as an emblem of the Deity, &c. . . .	3
,, various means of obtaining . . . .	3
,, when made from crude materials, how to be managed to produce complete combustion . . . .	6
<i>Fire-Bar</i> , for retort-furnace, description of . . . .	160
<i>Fittings-up</i> , tubing to be used for, described . . . .	352
,, directions relative to . . . .	358
<i>Flame</i> , of what it consists . . . .	4
,, when perfect and brilliant . . . .	4
,, matter for producing it should be at a proper heat . . . .	6
,, how to be thrown into the atmosphere, so as to be wholly decomposed . . . .	6
,, how weakened . . . .	6
,, small one proportionally brighter than a large one . . . .	7
,, bodies capable of producing it, what they contain . . . .	9

	Page
<i>Flame</i> , may be tinged of various colours, and by what means	10
,, remarks on the colours of, when produced from coals and wood . . . . .	11
,, of a common candle, remarks on the shades of colour it exhibits . . . . .	11
,, transparent . . . . .	35
,, of gas-burner, remarks on the lengths of . . . . .	36
<i>Flames</i> , for producing light, if brought into contact with each other, why beneficial . . . . .	35
<i>Flanch Pipe</i> , description of . . . . .	339
<i>Fluids</i> , movable every way . . . . .	275
,, surfaces of, rest in horizontal planes . . . . .	275
,, press equally on every part of the base of the vessel containing them . . . . .	276
,, all parts of, press equally at the same depth . . . . .	276
,, press equally in all directions whatever . . . . .	276
,, pressure of, on the base of a vessel, is as the base and perpendicular height . . . . .	279
<i>Franklin's, Dr. B.</i> , suggestions relative to using two candles so near each other as to allow the flames to unite . . . . .	34

## G.

<i>Gas, Portable</i> , Mr. David Gordon obtains a patent for vessels to contain . . . . .	104
,, procured from turf . . . . .	107
,, average quantity of, produced from a ton of coals in London, in 1837 . . . . .	123
,, average quantity of, produced from a ton of coals at sundry places . . . . .	167
,, why to be condensed (or refrigerated) before being submitted to the purifying process . . . . .	205
,, impure, the use of it to be avoided . . . . .	206
,, purity of, depends very much upon condensation . . . . .	206
,, the levity of, particularly observable in theatres. . . . .	351
,, requires to be thoroughly purified to produce a good light . . . . .	412
,, coal, price of, not depending altogether upon the price paid for coals . . . . .	417

	Page
<i>Gas-Burner</i> , how to ascertain the illuminating power of .	22
„ Argand, not to be used without a chimney-glass . . . . .	36
„ account of improvements in the manufacture of,	354
„ Argand, shank described . . . . .	353
„ ditto 12-hole, dimensions of . . . . .	353
„ ditto 15-hole, ditto . . . . .	354
„ one sometimes used as a street-light, description and dimensions of . . . . .	355
„ bat's-wing, description of . . . . .	355
„ fish-tail, or swallow's-tail, description of . . . . .	356
„ ditto or bat's-wing, upright socket for . . . . .	357
„ ditto ditto elbow socket for . . . . .	357
„ with a single jet of flame . . . . .	356
„ yielding three jets of flame. . . . .	356
„ yielding eight jets of flame. . . . .	356
„ improved Argand, manufactured by Messrs. Platow and Co., described . . . . .	355
<i>Gas-Conductors</i> , remarks upon the diameters of . . . . .	203
<i>Gas-Cooking Apparatus</i> , adverted to, and where manufactured . . . . .	416
<i>Gas-Heating Stoves</i> , for warming churches, &c., described .	415
<i>Gas-Holder</i> (gasometer), its use . . . . .	265
„ how the gas is prevented from escaping out of it,	266
„ to produce a proper light, at what pressure to be worked . . . . .	267
„ an equilibrium can be effected between it and the balance-weight . . . . .	268
„ how to ascertain the pressure at which it works	268
„ pressure of, how to be regulated . . . . .	269
„ one of its uses is to regulate the emission of the gas . . . . .	269
„ weight of, increases as it rises . . . . .	269
„ some contrivance necessary for making the pressure equal at all heights of its rise . . . . .	270
„ equality of pressure, how obtained in the early period of gas-lighting . . . . .	270
„ equality of pressure effected by the chain of suspension. . . . .	271

	Page
<i>Gas-Holder</i> , rule for ascertaining the weight of the suspension-chain for effecting an equal pressure, with examples thereon . . . . .	271
„ of 15,000 cubic feet capacity, how constructed	292
„ formerly encumbered with wooden frames or iron stays . . . . .	293
„ Mr. Clegg's revolving one, noticed . . . . .	298
„ cylindrical, on the ordinary principle, described,	266
„ ditto Mr. Malam's mode of constructing, with upright centre column . . . . .	302
„ collapsing one of Mr. Clegg's invention, noticed . . . . .	298
„ patent obtained for one by Mr. William Stratton, for doubling its capacity in the ordinary tank	299
„ suspended from four or more points at the circumference, description of . . . . .	305
„ suspended from three points at the circumference, description of . . . . .	309
„ telescope, remarks upon its action . . . . .	315
„ ditto description of one . . . . .	317
„ pressure at which it works, how to calculate . . . . .	294
<i>Gas-Holders</i> , proposed to be worked with air-vessels for equalizing pressure of, noticed . . . . .	298
„ should always be placed in the open air, and as far from the retort-house as circumstances will permit . . . . .	449
<i>Gas-Light</i> , does not produce any smoke or emit sparks . . . . .	85
„ not so dangerous as candles and lamps . . . . .	85
„ not liable to be put out by sudden gusts of wind or heavy rain . . . . .	85
„ to whom the merit of bringing it into notice as a substitute for other lights is due . . . . .	88
„ its superiority over other artificial light, whence it arises . . . . .	414
„ how managed, so as to produce different intensities of light . . . . .	414
„ exceedingly applicable for use in light-houses . . . . .	415
„ cannot be manufactured with economy on a small scale . . . . .	416

	Page
<i>Gas-Light Companies</i> , on what they rest their claims to public notice . . . . .	62
<i>Gas-Light Manufactory</i> , arrangement of, must always depend upon local circumstances . . . . .	448
,, low situation of, near a river or canal, why to be preferred . . . . .	448
<i>Gas-Meter</i> , history of its origin . . . . .	361
,, Mr. Clegg's first (or reciprocating), described . . . . .	361
,, ditto patent rotary one, described . . . . .	363
,, Mr. John Malam submits one to the Chartered Gas-Light Company, Westminster . . . . .	364
,, its usefulness for ascertaining the quantity of gas generated . . . . .	360
,, Mr. Malam's first, description of . . . . .	368
,, ditto improved, description of . . . . .	373
,, would be a check upon the stokers. . . . .	375
,, dial of, should be accessible to the manager of the gas-works only. . . . .	376
,, its use advantageous to the manufacturer . . . . .	376
,, ditto consumer of gas . . . . .	376
,, use for economizing the consumption of gas . . . . .	378
,, remarks on its use in private houses, shops, &c. . . . .	376
,, dry ones noticed . . . . .	379
,, Mr. John Malam's patent wet meter, noticed . . . . .	379
,, Mr. John Hemming's patent protector gas-meter, described . . . . .	380
,, float-valve of, for keeping water at a proper level . . . . .	382
,, may be relied upon as a correct measurer . . . . .	382
<i>Gas-Moderator</i> , manufactured by Messrs. Platow and Co., described . . . . .	394
<i>Gas-Regenerators</i> , patented by Mr. John Malam . . . . .	420
,, description of, and furnaces . . . . .	421
,, operation of, and results produced from working them . . . . .	424
,, advantages they hold out to the gas manufacturer . . . . .	427
,, advantages further stated . . . . .	432
<i>Governor</i> , why first thought of, and the object it was intended to accomplish . . . . .	383

	Page
<i>Governor, Mr. Samuel Clegg obtains a patent for one</i> . . . . .	383
„ description of one . . . . .	384
„ large one to be used in the gas manufactory, description and use of . . . . .	389
„ where usefully employed . . . . .	395
<i>Ground Plan of the gas-works at Bury St. Edmunds, described</i> . . . . .	443

## H.

<i>Hales, Dr., made chemical experiments upon pit-coal</i> . . . . .	72
<i>Heat, best for working retorts at, and why so</i> . . . . .	411
<i>Heated-medium, for passing gas through after it had left the hydraulic main, tried by the author many years ago, and abandoned</i> . . . . .	418
<i>Henry's, Dr. W., account of Mr. Murdoch's discoveries and experiments on pit-coal</i> . . . . .	81
„ results of experiments on the quantity of oxygen required for burning different species of carburated-hydrogen gas . . . . .	412
<i>Hydraulic Main, description and use of</i> . . . . .	196
„ advantages arising from the use of . . . . .	198
„ remarks relative to the pressure thereon . . . . .	200
„ with the dip-pipes forms a series of hydraulic joints . . . . .	201
„ importance of its being well constructed . . . . .	202
„ gas therein has exploded . . . . .	202
„ to be kept as distant from the retorts as possible . . . . .	203

## I.

<i>Iron-founder, coke produced in ovens for heating the retorts, fit for use of</i> . . . . .	130
---	-----

## L.

<i>Lamp, shadowless overflowing, or meteor lamp</i> . . . . .	9
„ ditto consumption of oil per hour . . . . .	28

	Page
<i>Lamp</i> , solar . . . . .	9
„ ditto consumption of oil per hour . . . . .	28
<i>Lamps</i> , quality of combustible material for . . . . .	12
„ use of the wick of . . . . .	12
<i>Liebig</i> , Professor, aids Mr. Thomas Richardson in examining the exact proportions of each ingredient contained in various specimens of coals . . . . .	405
<i>Light</i> , procured by the agency of fire . . . . .	2
„ proportions of, afforded by candles when newly snuffed, and when requiring snuffing . . . . .	7
„ evolved by artificial means, whence derived . . . . .	10
„ strength of, decreases in what proportion with the distance from the point of divergency . . . . .	18
„ remarks on ascertaining its intensity when obtained from candles, lamps, &c. . . . .	18
„ travels in straight lines, and in every direction from its point of divergency . . . . .	18
„ emitted from any luminous body, how it becomes dilated, explained by a diagram . . . . .	18
„ afforded by candles of different sizes, or other luminous bodies, rules for ascertaining comparative proportions of . . . . .	20
„ comparative cost of as obtained from different substances . . . . .	28
„ from coal-gas to be good, the gas must be thoroughly purified . . . . .	412
<i>Light</i> , Artificial, from whence it arises . . . . .	5
„ how much of its effect is lost . . . . .	5
„ resources in this country for supplying it . . . . .	35
<i>Lights</i> , strength of various, how compared . . . . .	30
<i>Light-Houses</i> might be furnished with a better light from gas than in the ordinary way of lighting, and at less expense . . . . .	415
<i>Llandaff</i> , the Bishop of, examines the qualities of the products obtained from coal . . . . .	80
<i>Lowe</i> , Mr. George, uses double retorts set end to end, and how worked . . . . .	430
<i>Lowe</i> , Mr. George, and Mr. John Kirkham, take out a patent for a mode of combining and working retorts . . . . .	431

	Page
<i>Lowe, Mr. George, and Mr. John Kirkham, patent retorts, mode of operation thereof described</i> . . . . .	431
<i>Lowther, Sir James, coal-mine of, shaft takes fire</i> . . . . .	73

## M.

<i>Maiben's, Mr., of Perth, observations on the distillatory process, his retort, &amp;c.</i> . . . . .	121
<i>Main Pipes, when to be laid, steps necessary to be taken</i> . . . . .	343
„ how diameters of should be arranged . . . . .	344
„ socket described . . . . .	335
„ do. how jointed together . . . . .	336
„ Roman-cement used for making good the joints of socket pipes . . . . .	337
„ flanch described . . . . .	339
„ do. cement for forming joints of . . . . .	339
„ branches, description and use of . . . . .	340
„ outlets, description and use of . . . . .	341
„ bend, description and use of . . . . .	341
„ ess, description and use of . . . . .	341
„ description and use of thimble-joint used upon . . . . .	342
„ for conveying gas, might be lighter than those for water . . . . .	343
„ rule for ascertaining the diameter of, for supplying a given quantity of gas . . . . .	346
„ Dr. Ure's formula for ascertaining the diameters of, for supplying a given quantity of gas, the length of pipe being taken into consideration . . . . .	346
„ rule (practical one) for ascertaining the diameter of, for supplying a given quantity of gas . . . . .	347
„ to be laid with a certain declivity . . . . .	349
„ better supply of gas from, in elevated than in low situations . . . . .	350
<i>Malam, Mr. John, condensing vessels of his invention described</i> . . . . .	212
„ invents a treble wet-lime purifier . . . . .	238
„ description of his treble purifier . . . . .	238

<i>Malam, Mr. John</i> , description of the action of his treble purifier . . . . .	241
„ patent dry-lime purifier described . . . . .	247
„ double hydraulic valve described . . . . .	324
„ ditto ditto pressure it will sustain . . . . .	326
„ pneumatic valve described . . . . .	326
„ ditto is of a small size, and got up at a trifling expense . . . . .	328
„ exhibits a model of a gas-meter . . . . .	364
„ gas-meter invented by, disputed by Mr. Clegg . . . . .	365
„ has the gold Isis medal of the Society of Arts voted to him for his gas-meter . . . . .	366
„ his first gas-meter on the principle of Archimedes' screw . . . . .	367
„ gas-meter of, described . . . . .	368
„ improved gas-meter of, described . . . . .	373
„ dry gas-meter noticed . . . . .	379
„ wet-meter, for which he obtained a patent in 1835, noticed . . . . .	379
„ regulator of, described . . . . .	386
„ dimensions of, for supplying four lights . . . . .	388
„ regulator of, capable of sustaining a very heavy pressure . . . . .	388
„ takes out a patent for gas-regenerators . . . . .	420
„ gas-regenerators of, and furnaces described . . . . .	421
„ ditto operation of. . . . .	424
„ ditto advantages they hold out to the manufacturer of gas . . . . .	427
<i>Malting</i> , coke produced in oven for heating retorts, answers „ exceedingly well for . . . . .	130
<i>Montauban, the Marquis of</i> , proposed method of converting coal-tar into carburetted-hydrogen gas . . . . .	409
„ takes out a patent for a distillatory vessel in addition to the retort ordinarily used, which he calls “a decomposer” . . . . .	429
„ decomposer of, described . . . . .	429
<i>Murdock's, Mr.</i> , experiments on pit-coal at Old Cumnock, in Ayrshire. . . . .	82

	Page
<i>Murdoch s, Mr.</i> , experiments on pit-coal at Redruth, in Cornwall . . . . .	83
„ gas apparatus at Soho foundry . . . . .	83
„ account of lighting the whole of Mr. Lee's cotton-mill with gas, in which the saving of expense is noticed . . . . .	96

## N.

<i>Northern's, Mr.</i> , account of applying coal-gas for the purpose of producing light . . . . .	89
--	----

## O.

<i>Oil</i> , burnt in lamps with different sized wicks, experiments relative to the expense of . . . . .	34
<i>Oil-gas</i> , apparatus for making, protected by a patent . . . . .	101
„ from what obtainable . . . . .	101
„ bulk of, stated to be equal in illuminating power to more than thrice its bulk of coal-gas . . . . .	102
„ scheme why abandoned . . . . .	103
<i>Oil, seed</i> , { cost of obtaining light from, compared with	
„ <i>sperm</i> , { cost of obtaining light from wax-candles,	
„ <i>whale</i> , { mould or ill-snuffed tallow-candles and coal-	
gas . . . . .	26—28
<i>Olefiant-gas</i> , produced from pit-coal . . . . .	408
„ coal producing greatest proportion of, most profitable . . . . .	408
<i>Outlet-Pipe</i> , description and use of . . . . .	341

## P.

<i>Palmer, Mr.</i> , candles of, with metallic wicks . . . . .	8
<i>Perks, Mr. John</i> , patent condenser of, described . . . . .	210
<i>Phillips, Mr. R.</i> , obtains a patent for purifying coal-gas by means of dry lime . . . . .	242
„ dry-lime purifier described, and how used . . . . .	243
„ ditto advantages attending use of . . . . .	246

	Page
<i>Pipes</i> , connecting, for retorts, described . . . . .	196
„ dip and H, for retorts, described . . . . .	196
<i>Portable Gas</i> , London Portable Gas-light Company noticed . . . . .	104
<i>Pressure</i> , frequently confounded with weight . . . . .	275
„ of fluids on vessels having equal bases, but of different capacities, exemplified by an experiment . . . . .	281
„ upon every square inch of the top of the gas-holder how ascertained . . . . .	295
<i>Protector Gas-Meter</i> , Mr. Hemming's patent one . . . . .	380
<i>Purification of Coal-Gas</i> , why it should be properly performed . . . . .	230
„ general modes of performing the . . . . .	231
„ by lime in mechanical solution, . . . . .	
how first effected . . . . .	233
„ effected by Mr. Malam's treble . . . . .	
wet-lime purifier . . . . .	238
„ by lime in a semi-fluid state . . . . .	232
„ effected by dry lime . . . . .	243
„ attempted by passing it through . . . . .	
heated metal tubes . . . . .	232
„ from ammonia, how proposed to . . . . .	
be effected by M. Blondeau de Carolles . . . . .	261
„ (patent for) from ammonia, &c., . . . . .	
obtained by Mr. A. A. Croll, describing his mode of procedure to effect that object . . . . .	262
„ lime to be used for effecting it . . . . .	263
<i>Purifiers</i> , description of dry-lime ones, patented by Mr. R. Phillips . . . . .	243
„ description of dry-lime ones, patented by Mr. John Malam . . . . .	246
„ Mr. John Malam's patent dry-lime purifiers, advantages attending the use of . . . . .	259
„ remarks as to where sometimes placed, in order that all the connexions to them might be accessible . . . . .	448
<i>Purifying Vessel</i> , the pressure it is worked at explained . . . . .	200
„ necessity of means being adopted for giving notice of any impediment therein . . . . .	201
„ square, or parallelopipedal why not equal to round one . . . . .	237

## R.

	Page
<i>Receiver</i> , for inlet and outlet pipes to and from gas-holder, described . . . . .	331
<i>Regulator</i> , for correcting inequalities of pressure upon burners . . . . .	383
„ large one, for supplying a town or district, de- scribed . . . . .	389
<i>Retorts</i> , different kinds of, used . . . . .	109
„ circular (or cylindrical), description of . . . . .	110
„ circular, performance of, when set two to one fire . . . . .	110
„ ditto ditto set three to one fire . . . . .	111
„ ditto ditto set four to one fire . . . . .	112
„ circular, when set four to one fire the top ones fail first . . . . .	114
„ ovens for heating them first adopted . . . . .	115
„ advantages of elliptical or large D-shaped over cy- lindrical ones . . . . .	118
„ elliptical, proposed to be used . . . . .	125
„ ditto, advantages arising from the use of . . . . .	126
„ large D-shaped . . . . .	127
„ semicircular, observations upon . . . . .	129
„ kidney-formed . . . . .	130
„ square (so called) . . . . .	131
„ ditto, their action . . . . .	132
„ on the kind of workmanship which should be at- tended to in setting them . . . . .	135
„ as of clay, fire-tiles, &c., of various kinds submitted to the public . . . . .	139
„ square, description of mode of setting them . . . . .	141
„ method of setting five elliptical ones, in one oven, to be heated by two coke-ovens described . . . . .	142
„ kidney-shaped, plan for setting one over one fire described . . . . .	144
„ large D-shaped, description of setting three over an oven (with descending flues) and in such a way as will admit of the oven being worked either as a furnace or for making coke . . . . .	146

	Page
<i>Retorts</i> , small D-shaped, description of setting three over one furnace . . . . .	156
„ the most advantageous heat to work them at, and why so . . . . .	410, 411
<i>Richardson, Mr Thomas</i> , aided by Professor Liebig, examines the exact proportions of each ingredient contained in various specimens of coals . . . . .	405
<i>Rickets, Mr. C.</i> , manufactures gas-heating stoves and apparatus for cooking by gas . . . . .	416
<i>Rosin</i> , gas procured from . . . . .	103
<i>Rumford's, Count</i> , experiments on the quantity of materials necessary to produce a light of a certain intensity, for a given time . . . . .	26

## S.

<i>Seed-Oil</i> , compared as to cost for procuring light with cost of obtaining light by means of wax or tallow-candles, sperm or whale-oil, and coal-gas . . . . .	26—28
<i>Service Pipes</i> , description and use of . . . . .	351
„ to be laid sloping . . . . .	352
<i>Shadowless Lamp</i> , overflowing, or Meteor Lamp, noticed . . . . .	9
„ cost per hour for burning . . . . .	28
<i>Shadows</i> , produced by two or more luminous bodies, how to judge of the strength of . . . . .	19
<i>Shirley's, Mr. Thomas</i> , description of a burning well near Wigan, Lancashire . . . . .	69
<i>Short-lengths</i> , wrought-iron, described, and where used . . . . .	351
<i>Sight-hole and Frames</i> , description of . . . . .	144 and 151
<i>Sobolowsky and Horrer</i> , obtain carburetted-hydrogen gas from wood . . . . .	411
<i>Socket Pipe</i> , described . . . . .	335
„ turned and bored, much used, and where used advantageously . . . . .	338
<i>Solar Lamp</i> , noticed . . . . .	9
„ consumption of oil, and consequent cost of using it per hour . . . . .	28
<i>Specific Gravity</i> , of coal-gas, average of . . . . .	409

	Page
<i>Specific Gravity</i> of coal-gas obtained when working the gas-regenerators . . . . .	426
„ of coal-gas, directions and rules for ascertaining . . . . .	435
<i>Sperm-Oil</i> , compared as to cost for procuring light with light obtained from burning wax and tallow-candles, whale and seed-oil, and coal-gas . . . . .	26—28
<i>Station Gas-Meter</i> , dial of, should be accessible to the manager of a gas manufactory only . . . . .	376
„ sometimes has mechanism attached thereto for marking down with a pencil, or other tracer upon paper, the quantity of gas made every hour . . . . .	375
<i>Stratton's, Mr. William</i> , gas-holder, described . . . . .	299
„ ditto, action of . . . . .	301
„ ditto, compensation of pressure well effected . . . . .	302
<i>Sulphuretted-Hydrogen</i> , produced from pit-coal . . . . .	406
<i>Syphon</i> , difficulty of accounting for the name of that (so called) used in the gas-light manufactory . . . . .	328
„ the different kinds of, noticed . . . . .	328
„ description of gun-barrel and bottle syphon . . . . .	330
„ gun-barrel, or bottle, where used . . . . .	330

## T.

<i>Table</i> of comparative illuminating power and expense per annum for burning coal-gas, tallow and wax-candles, and spermaceti oil . . . . .	37
„ showing the quantities of gas obtainable from several varieties of coals of the first class . . . . .	45
„ ditto, from coals of the second class . . . . .	49
„ showing the relative proportions of gas obtainable from coals of various kinds . . . . .	51
„ exhibiting the ratio at which gas is evolved when working the retorts at eight hours' charges . . . . .	170
„ last mentioned, use of exemplified . . . . .	171
<i>Tanks for Gas-Holders</i> , remarks on their construction . . . . .	285

	Page
<i>Tanks for Gas-Holders</i> , when of cast-iron, how to ascertain the proportional strength of each tier of plates . . . . .	286
"    when of brick or masonry, detailed instructions for making . . . . .	289
"    cast-iron one of thirty-four feet diameter described . . . . .	286
"    double one noticed . . . . .	288
"    circular preferable to square . . . . .	288
<i>Tar Cistern</i> , where it should be situated . . . . .	224
"    shape and construction of one of cast-iron . . . . .	226
"    ditto ditto of one of brick . . . . .	227
"    method of preventing the gas entering into it . . . . .	227
<i>Tar Well</i> , described, and where used . . . . .	330 and 331
<i>Tee-Pieces</i> , wrought-iron, description and use of . . . . .	351
<i>Telescope Gas-Holder</i> , mode of constructing described . . . . .	317
<i>Tests</i> , necessity of taking, and why so . . . . .	397
"    a self-acting test-card described, with remarks thereon . . . . .	398
"    most correct and satisfactory mode of taking . . . . .	399
"    a great number described in Dr. Henry's Chemistry, and also in Dr. Reid's Chemistry . . . . .	404
<i>Test</i> , for detecting sulphuretted-hydrogen gas, 1st . . . . .	399
"    ditto ditto 2nd . . . . .	400
"    ditto ditto 3rd . . . . .	401
"    ditto ditto 4th . . . . .	401
"    ditto ditto 5th . . . . .	402
"    ditto sulphuretted-hydrogen gas, or carbonic acid gas . . . . .	402
"    ditto carbonic acid gas . . . . .	403
"    ditto ammoniacal gas . . . . .	403
<i>Theory</i> of the production of gas-light compared with the theory of procuring artificial light by means of candles or lamps . . . . .	63
<i>Thimble-Joint</i> , description and use of . . . . .	342

U.

<i>Union-Joint</i> , description and use of . . . . .	356
---	-----

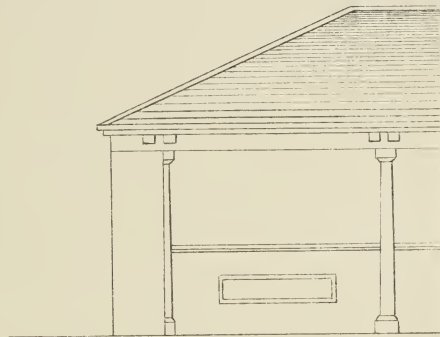
## V.

	Page
<i>Valves</i> , why necessary . . . . .	324
„ ordinary slide valves now used for most purposes in the gas-light manufactory . . . . .	324
<i>Valve</i> , double hydraulic, described . . . . .	324
„ pneumatic, described . . . . .	326
„ ditto, rule for its dimensions . . . . .	326
<i>Vats</i> , <i>Wooden</i> , for gas-holders to work in, remarks upon . .	288

## W.

<i>Walker</i> , <i>Mr. Ezekiel</i> , on a mode for preventing the fluctua- tion of light afforded by candles . . . . .	7
<i>Washer</i> , description of one . . . . .	217
<i>Watson</i> , <i>Dr.</i> , afterwards Bishop of Llandaff, publishes re- sults of his experiments for obtaining gas from pit-coal . . . .	80
<i>Wax-Candles</i> , cost of obtaining light from, compared with the cost of obtaining light from sperm-oil, whale or seed-oil, mould or ill-snuffed tallow-candles, and coal- gas . . . . .	26—28
<i>Whale-Oil</i> , cost of obtaining light from, compared with the cost of obtaining light from wax and tallow-candles, sperm-oil, seed-oil, and coal-gas . . . . .	26—28
<i>Winsor</i> , <i>Mr. F.</i> , some account of his labours for bringing the subject of lighting streets, houses, &c. &c., by means of coal-gas, before the public . . . . .	85—88

THE LIBRARY OF THE  
FEB 20 1929  
UNIVERSITY OF ILLINOIS



Scale  $\frac{1}{16}$  inch to a Foot.

FRONT ELEVATION



Scale  $\frac{1}{16}$  inch to a Foot.

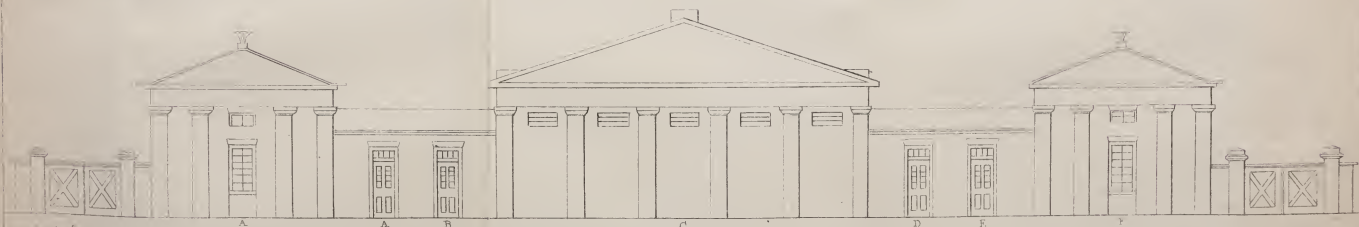
BACK ELEVATION OF THE GAS

S. Peckstone.



Scale  $\frac{1}{2}$  inch to a Foot

FRONT ELEVATION OF COKE STORE AT THE BURY ST EDMUNDS GAS WORKS

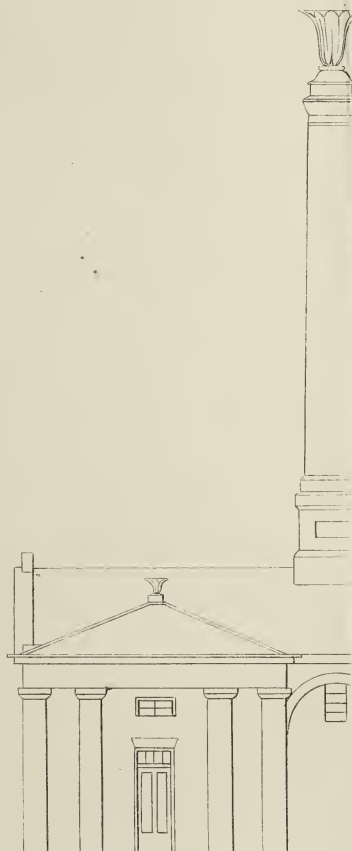


Scale  $\frac{1}{2}$  inch to a Foot

BACK ELEVATION OF THE GAS WORKS AT BURY ST EDMUNDS, SUFFOLK. ERECTED BY T S. PECKSTON IN 1834.

Thos S. Peckston

London. Published by E. Hebert, 22<sup>nd</sup> February 1841.



Scale  $\frac{7}{16}$  inch to a Foot

A

ton

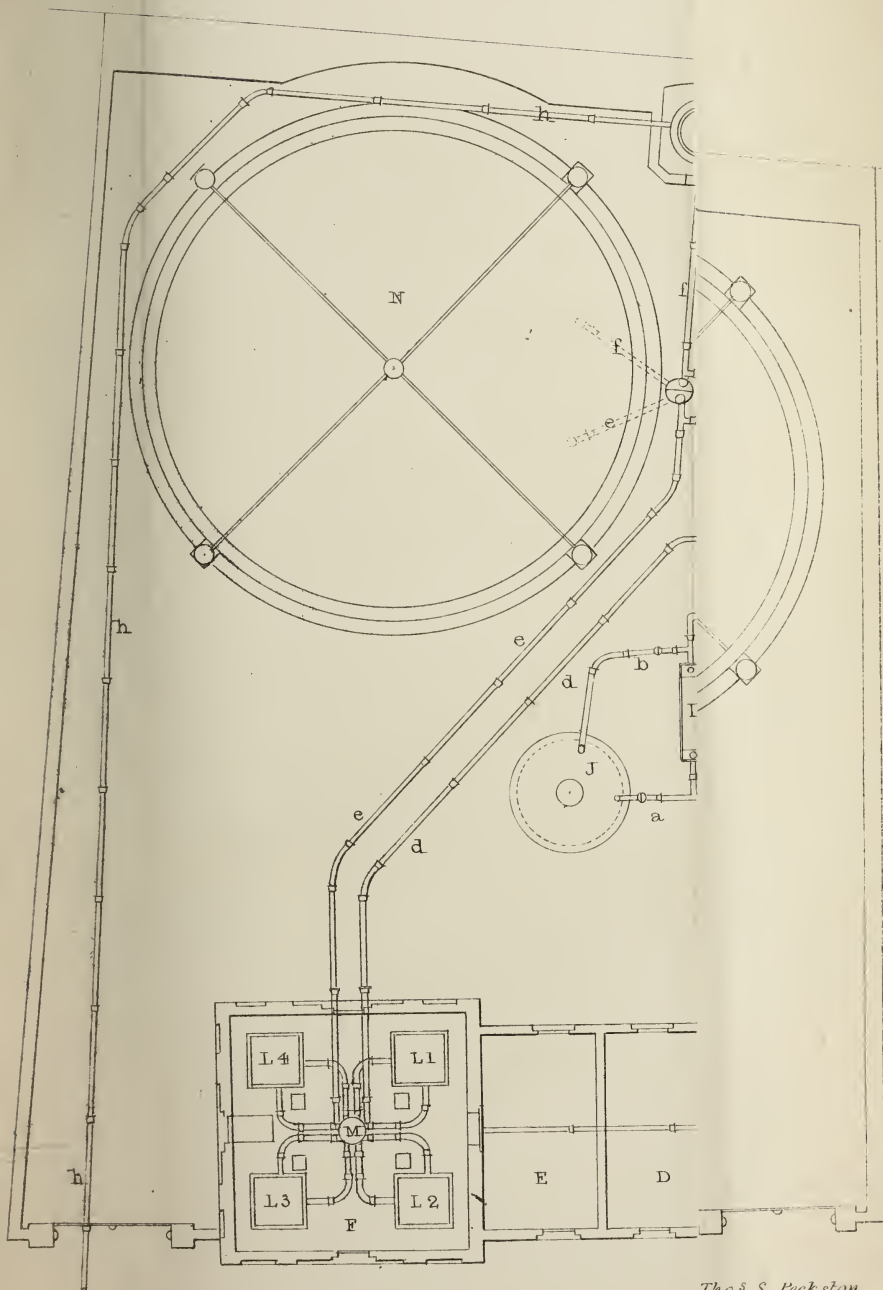
SIDE ELEVATION OF THE GAS WORKS AT BURY 334.



SIDE ELEVATION OF THE GAS WORKS AT BURY ST EDMUNDS, SUFFOLK, AND SHEWING ONE OF THE GAS HOLDERS, ERECTED BY T. S. PECKSTON IN 1834

London: Published by E. Herbert, 20<sup>th</sup> February 1841

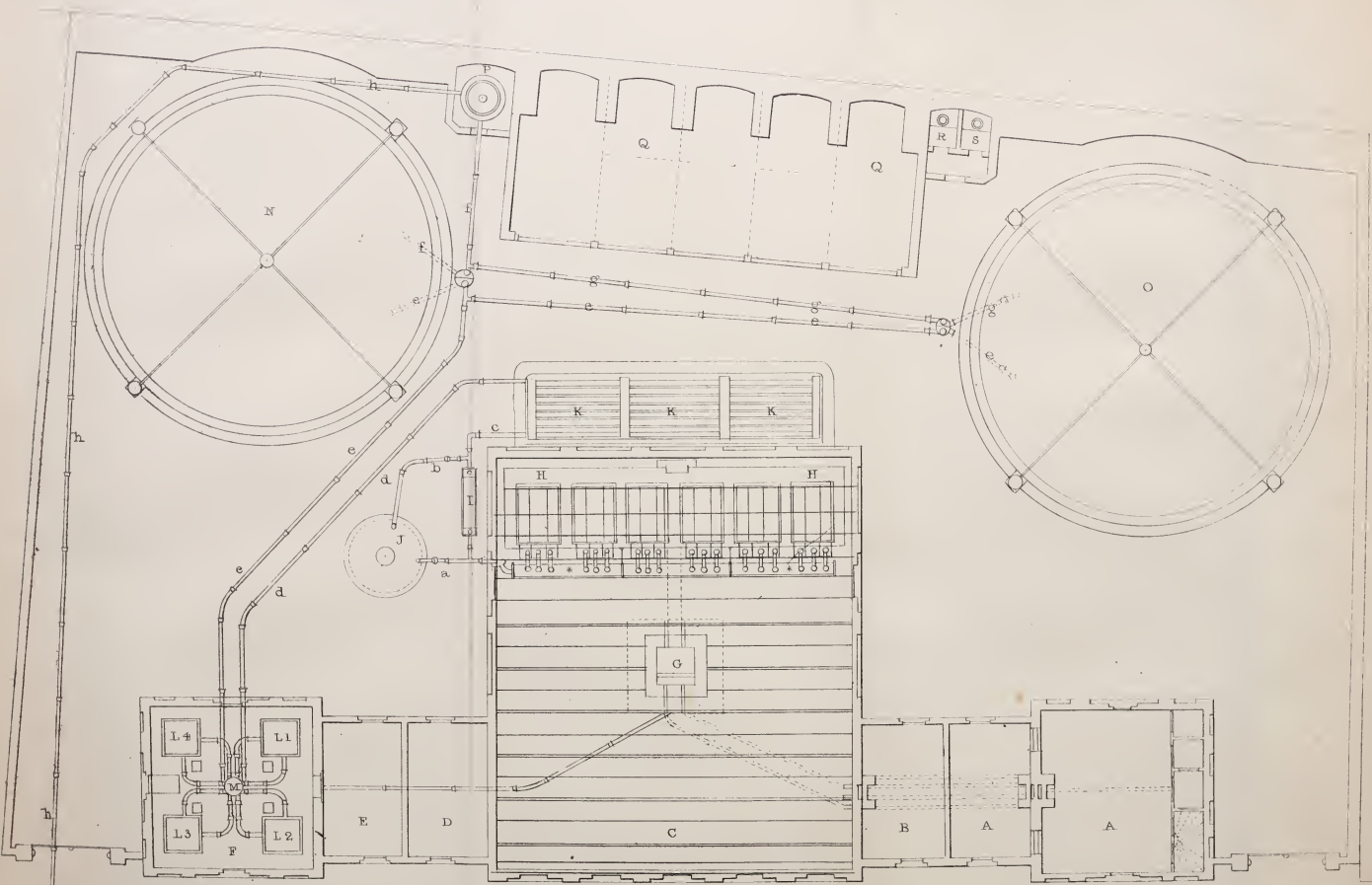
GROUND PLAN OF THE GAS V



Scale  $\frac{1}{16}$  inch to a foot

Tho:<sup>s</sup> S Peckston.

GROUND PLAN OF THE GAS WORKS AT BURY ST EDMUNDS, SUFFOLK, ERECTED BY T S PECKSTON IN 1834



Scale  $\frac{1}{2}$  inch to a foot

Thos S Peckston.

London Published by E Hebert, 20<sup>th</sup> Feb<sup>y</sup> 1841.

Fig. 1.

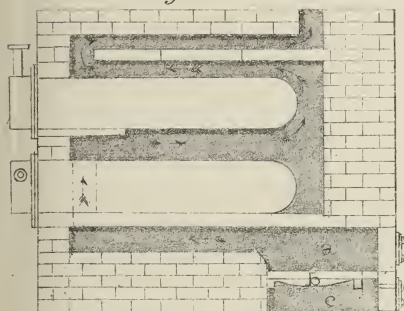


Fig. 2.

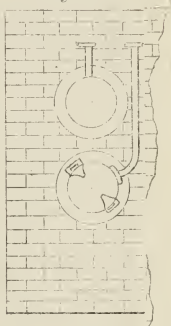


Fig. 4.

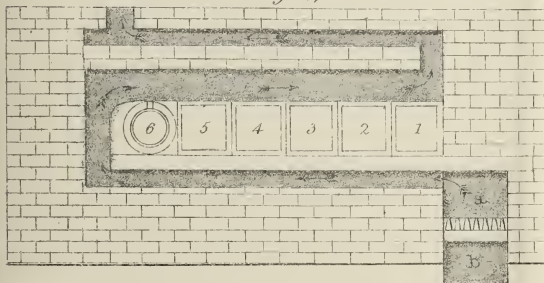
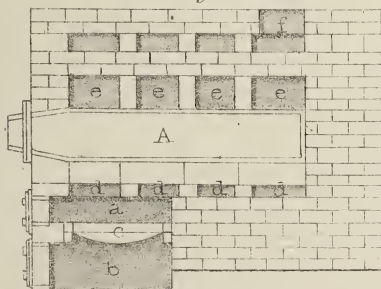


Fig. 5.



Tho<sup>s</sup> S. Peckston.

Fig 1.

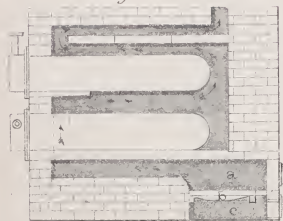


Fig 2.



Fig 3.

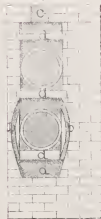


Fig 4.



Fig 5.

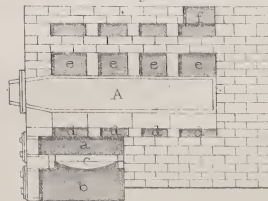


Fig 10.



Fig 11.

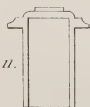


Fig. 6.

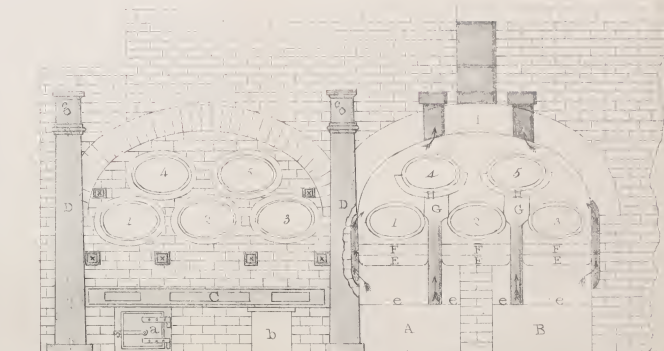


Fig. 7.

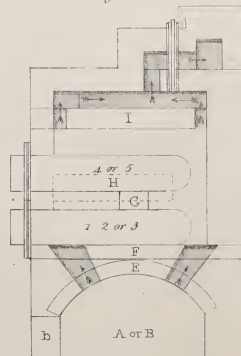


Fig. 8.

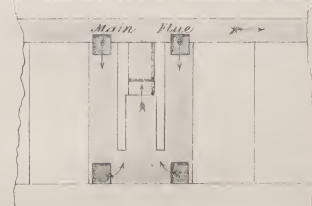
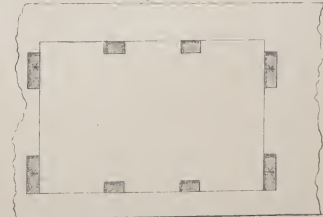


Fig. 9.



Thos<sup>d</sup> S. Peckston.

Fig: 1.

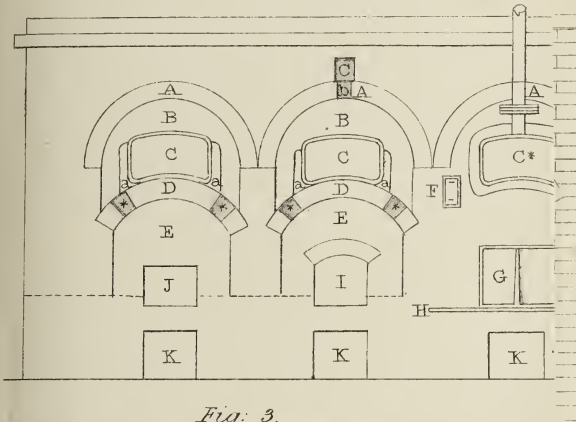


Fig: 3.

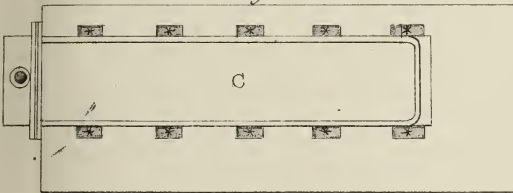


Fig: 8.

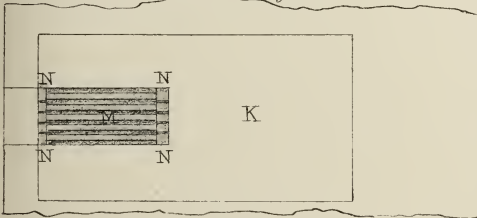
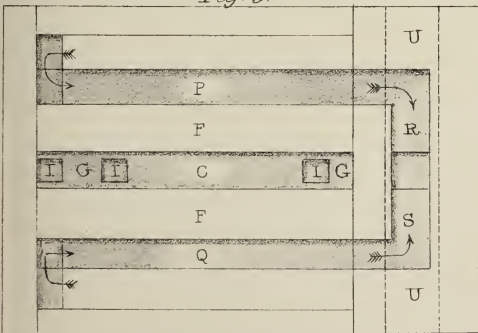


Fig: 9.



F. 12

Fig

ston.

Fig. 1.

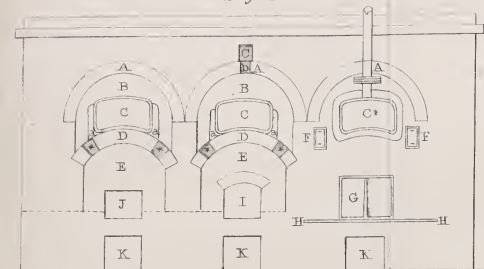


Fig. 2.

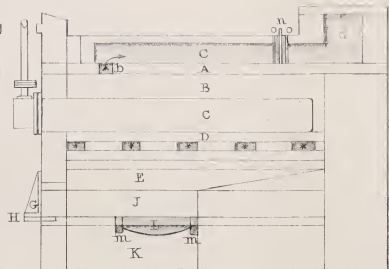


Fig. 5.

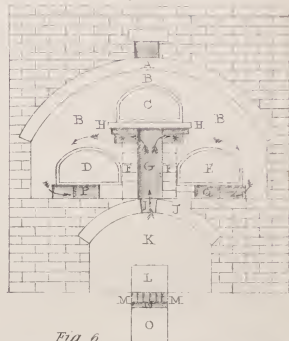


Fig. 3.



Fig. 11.



Fig. 4.

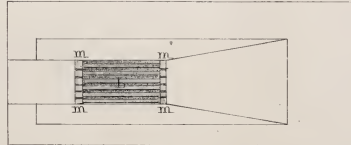
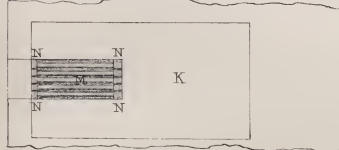


Fig. 8.



F. 12.

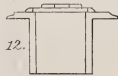


Fig. 10.

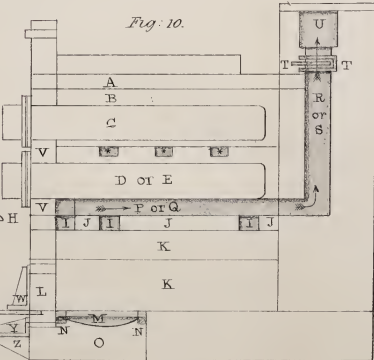


Fig. 13.

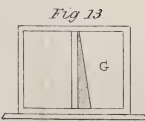


Fig. 9.

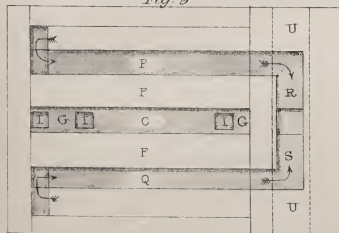


Fig. 14.

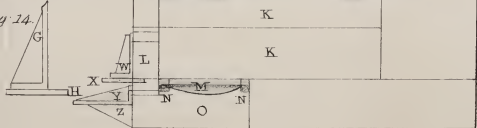


Fig. 6.

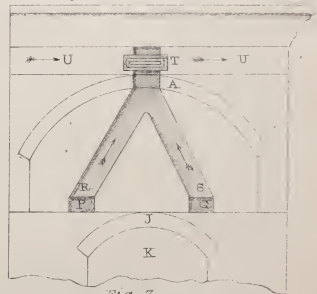
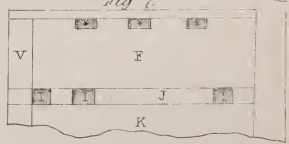


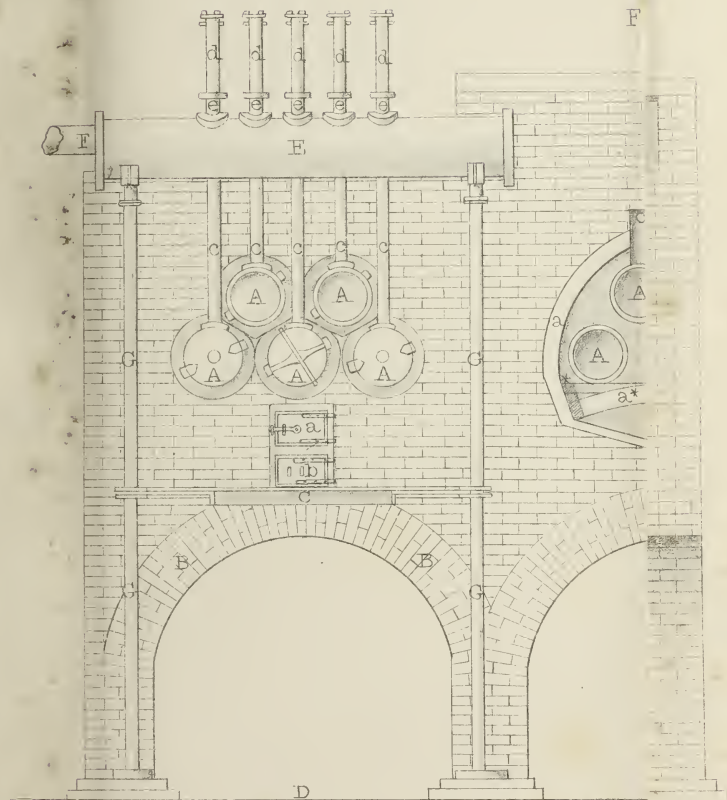
Fig. 7.



Thos. S. Peckham

London. Published by E. Hebert, 20<sup>th</sup> Feb<sup>y</sup> 1841

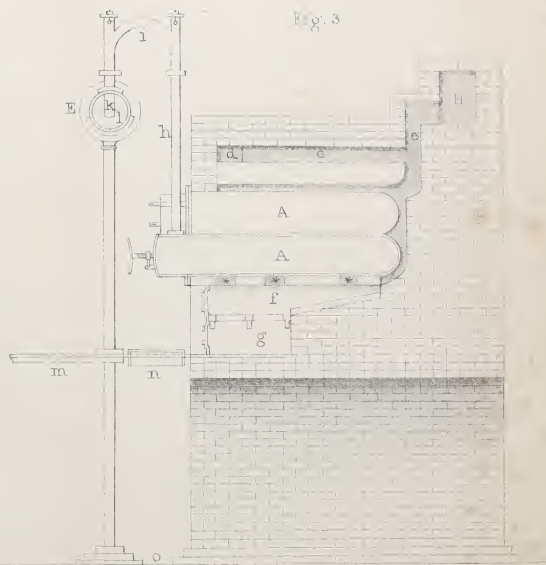
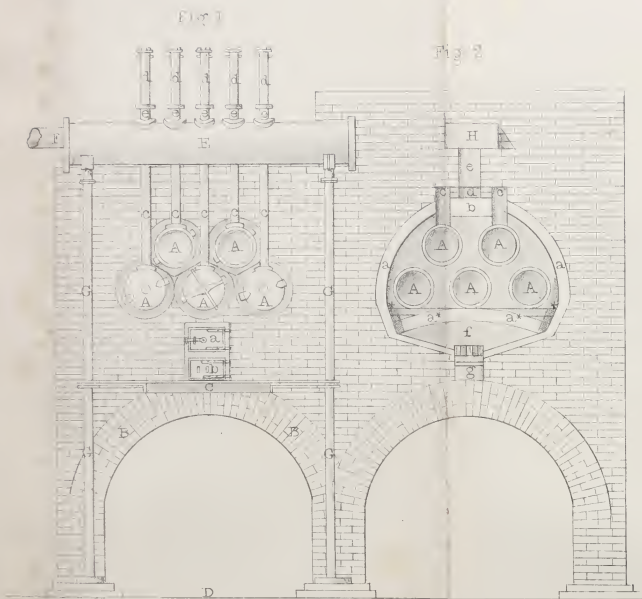
Fig. 1



Scale  $\frac{1}{4}$  inch to a Foot.

1

Lo



Scale  $\frac{1}{2}$  inch to a Foot

Thos. S. Peckston

London, Published by E. Hebert 20<sup>th</sup> February 1841

Fig. 1.

Plate 10.

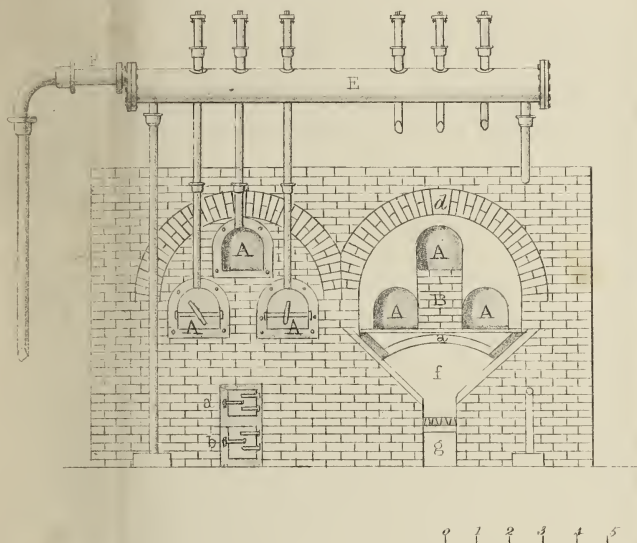


Fig. 6

Fig. 3.

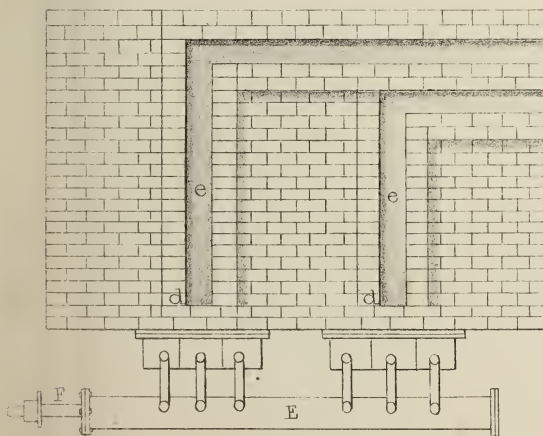


Fig. 10



Fig. 12.



Fig 1.

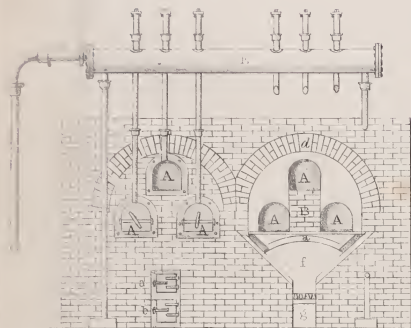
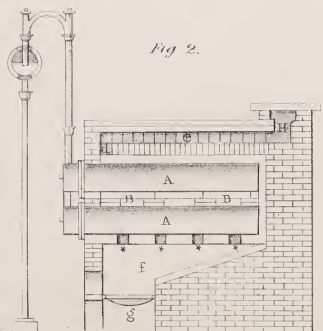


Fig 2.



0 1 2 3 4 5 100 Ft.

Fig 3.

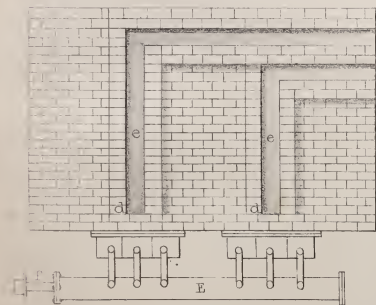


Fig 4.

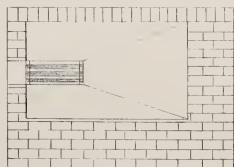


Fig 5.

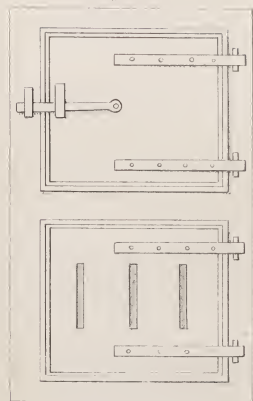


Fig 6.



Fig 7.



Fig 8.

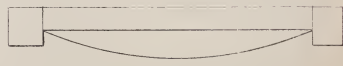


Fig 9.

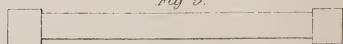


Fig 11.

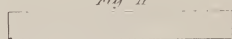


Fig 12.



Fig 10.



Thos S Peckston.

London. Published by E. Hebert 20<sup>th</sup> February, 1841.

Fig. 1.

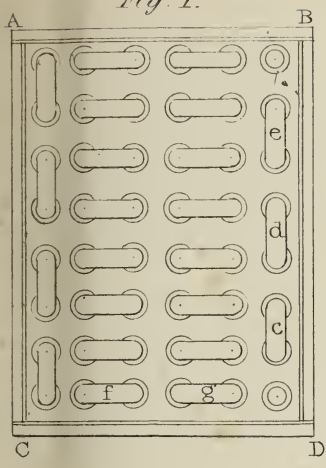


Fig. 2.

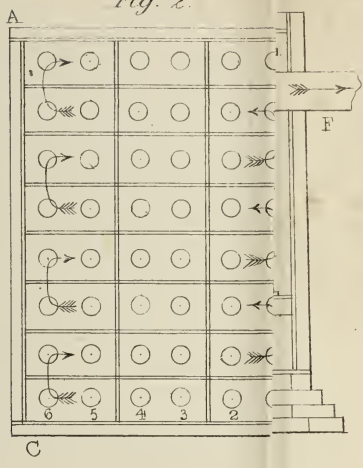


Fig. 3.

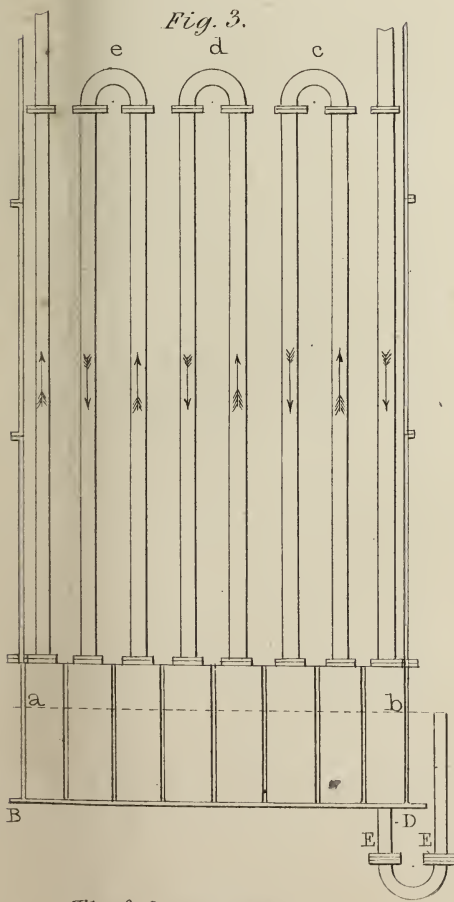


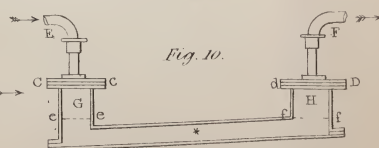
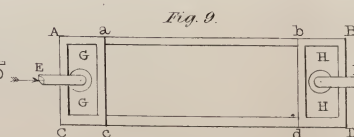
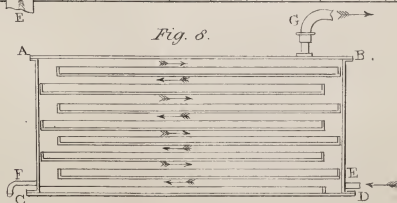
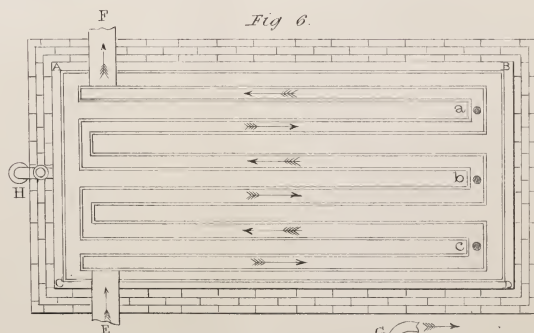
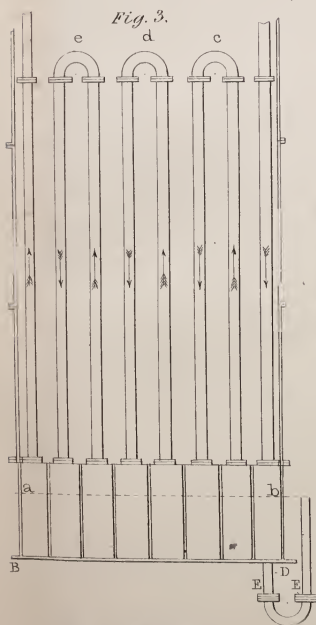
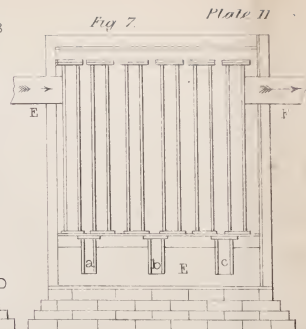
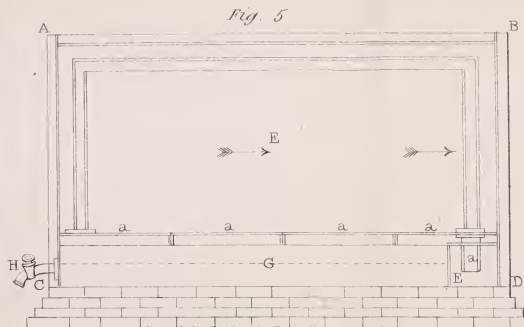
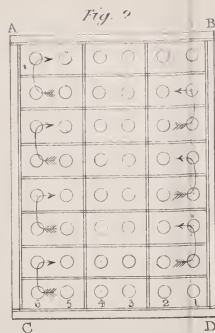
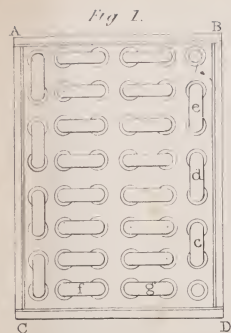
Fig. 4.



Thos. S. Peckston.

On Zinc, by C. Eulton

London.



Tho<sup>s</sup> S. Peckston

London. Published by E. Hebert, 20<sup>th</sup> Feb<sup>y</sup> 1841

On Line, by C. Burton

Day & Haghe, Lithog<sup>rs</sup> to the Queen

Fig. 1

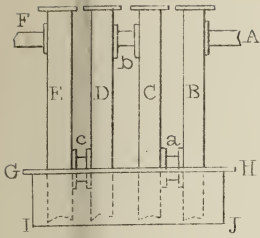


Fig. 2

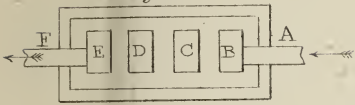


Fig.

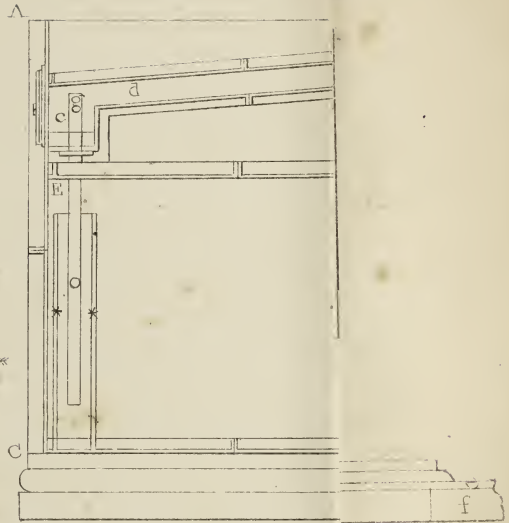


Fig.

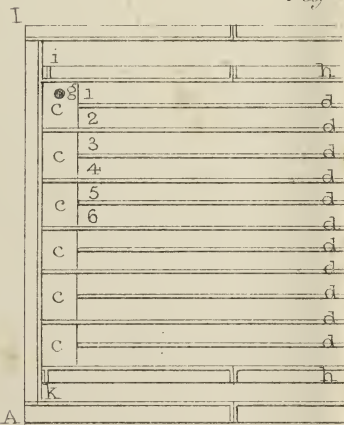
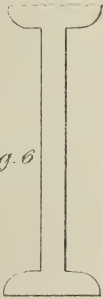


Fig. 5.



Fig. 6



Tho<sup>s</sup> S. Peckston.

London. Publishe

Curran, del.

e. Quen

Fig 1

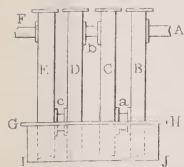


Fig 2

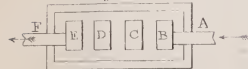


Fig 5



Fig 6

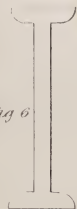


Fig 3

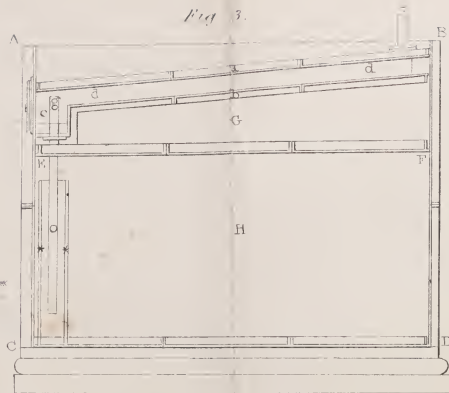


Fig 4

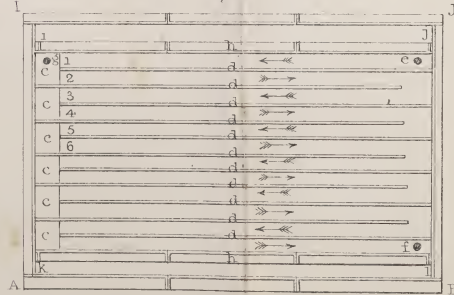


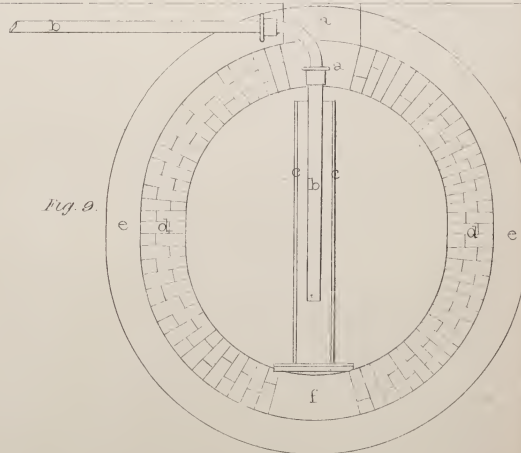
Fig 7



Fig 6



Fig 9



Thos S. Peckston

London. Published by E. Herbert, 20<sup>th</sup> Feb<sup>y</sup> 1841

Deposited with the Queen

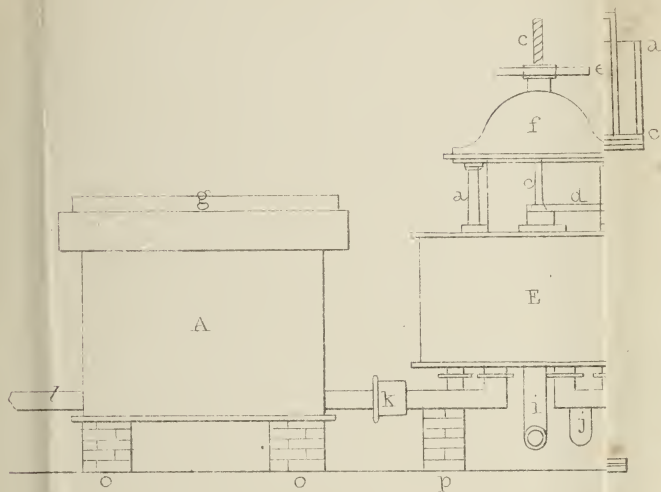


Fig. 2.

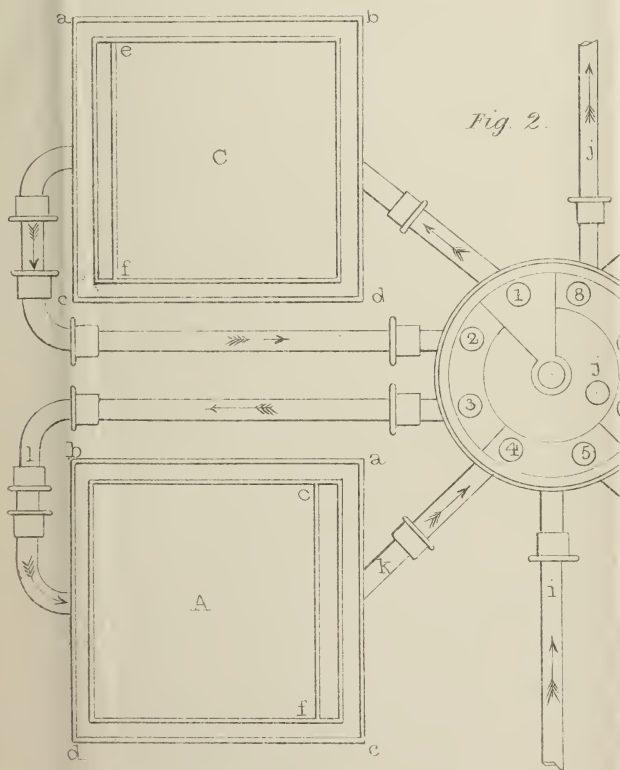


Fig. 1

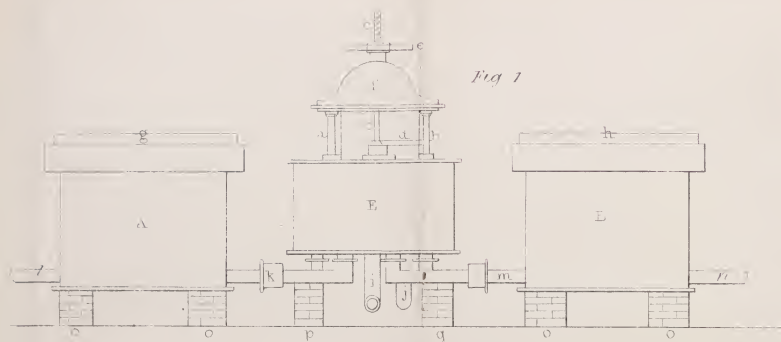


Fig. 3

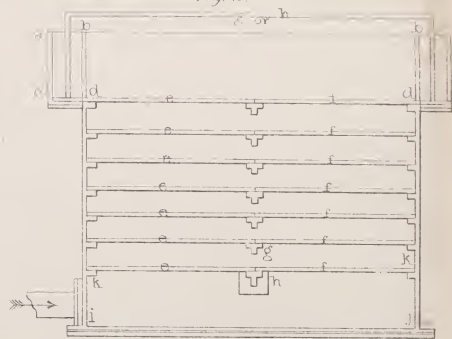


Fig. 2

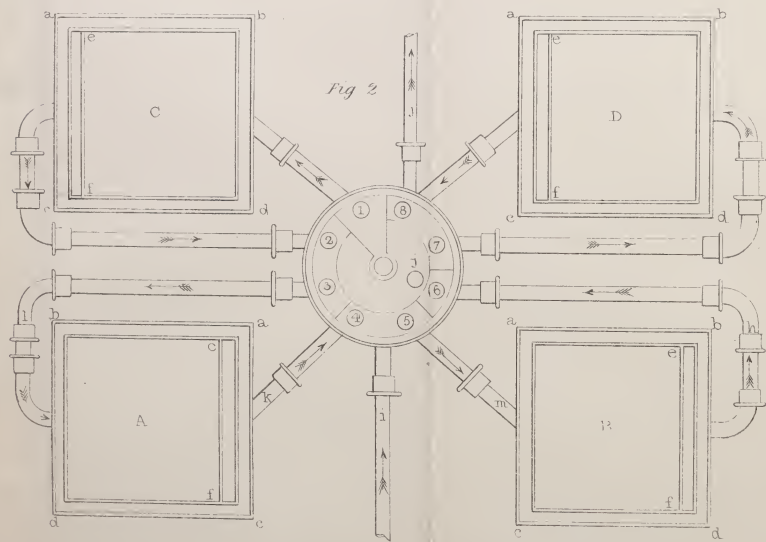
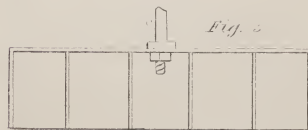


Fig. 4



Fig. 5



London: Published by E. Herbert 29 (W) Feb. 1841.

Thos. S. Peck-ston

Fig. 1.

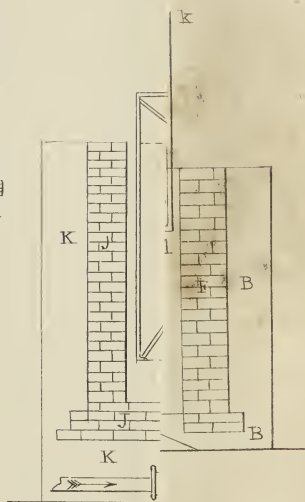
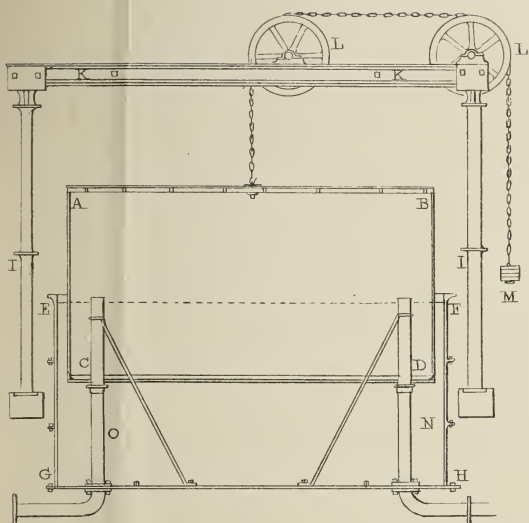
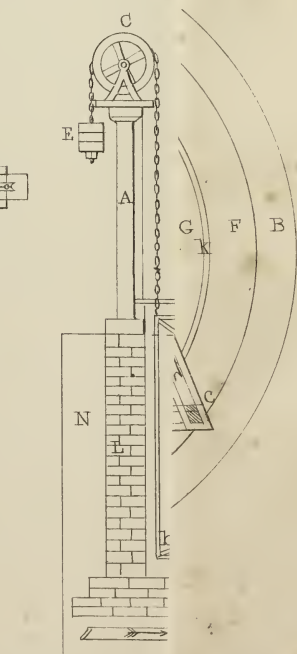
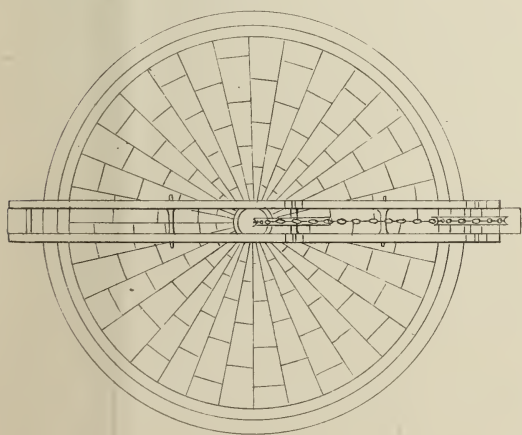


Fig. 2.



Tho<sup>s</sup> S. Peckston

C Burton, del<sup>v</sup>

the Queen

Lond<sup>n</sup>

Fig. 1.

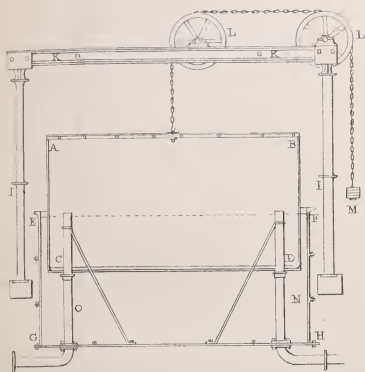
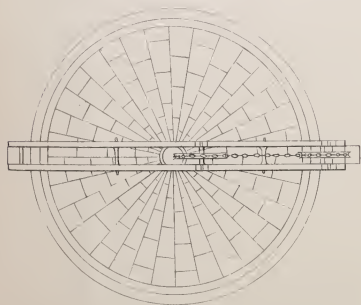


Fig. 2.



Tho: S Peckston

Fig. 3.

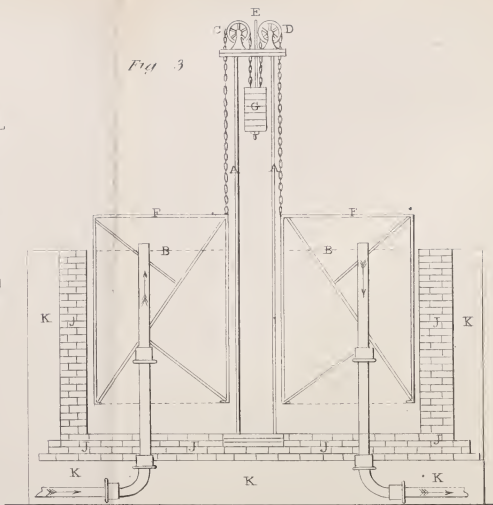


Fig. 4.

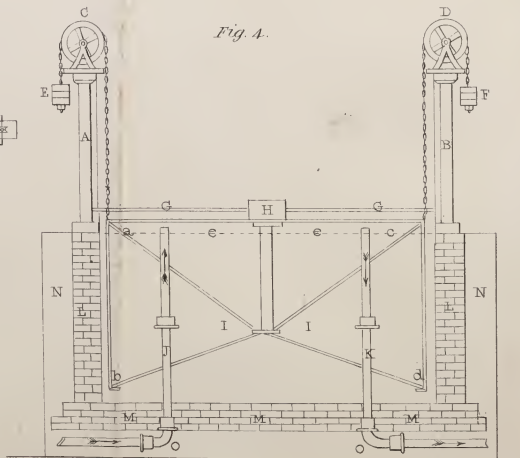


Fig. 5.

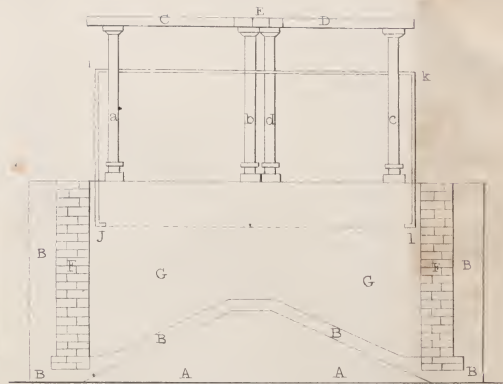


Fig. 6.

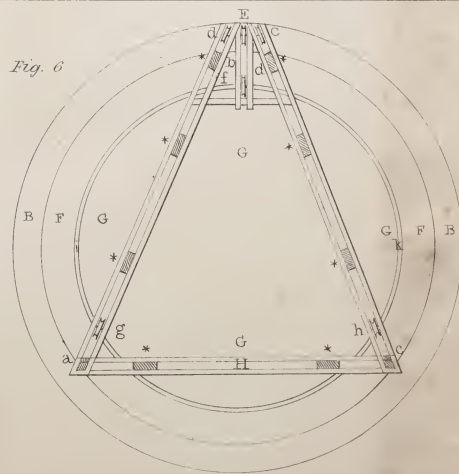
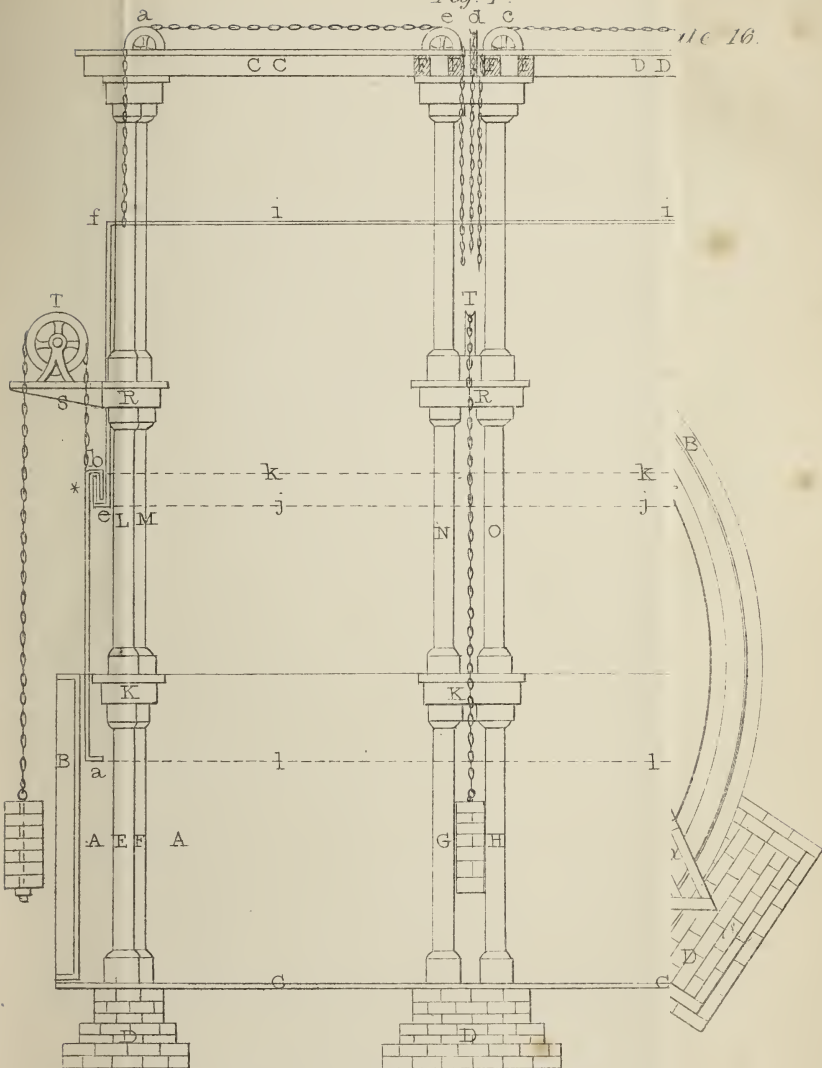


Fig. 1.



Scale  $\frac{7}{8}$  of an Inch to a Foot.

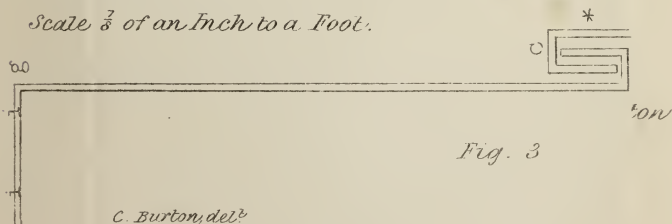
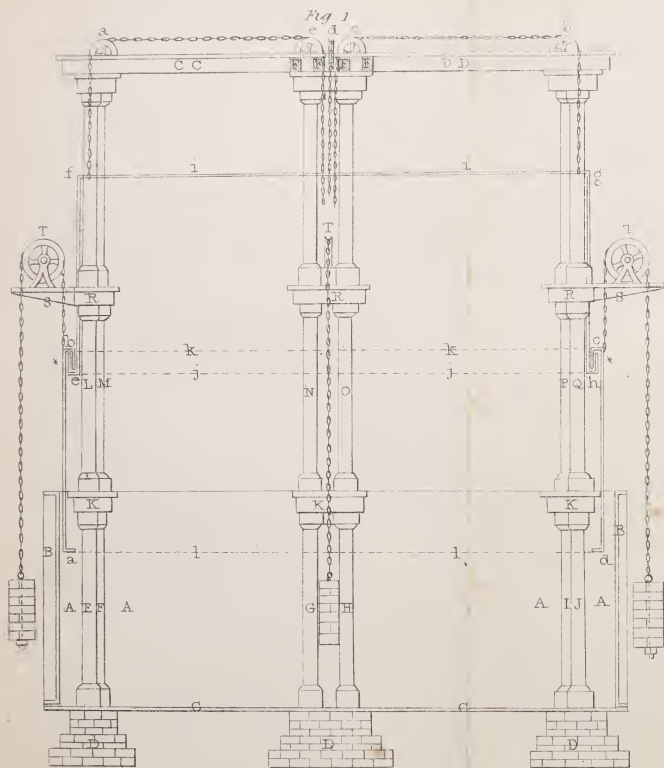


Fig. 3

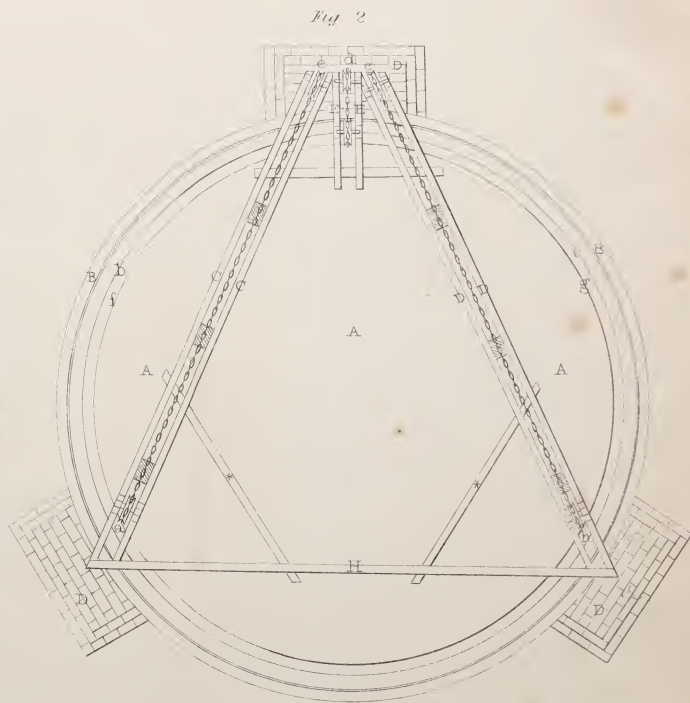
C. Burton, del.



Scale  $\frac{1}{2}$  of an Inch to a Foot.



C. Burton, del.



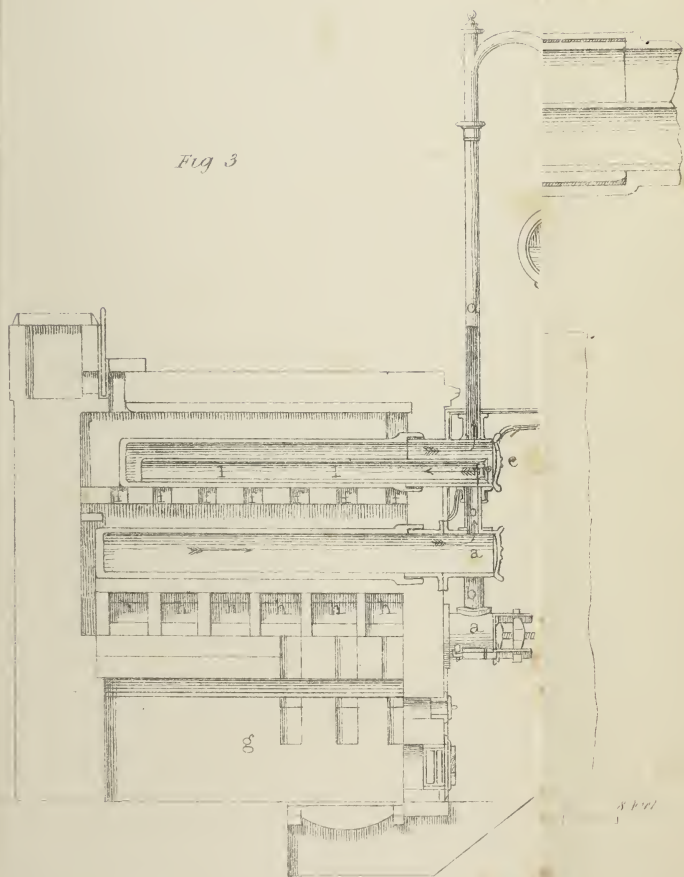
London Published by E. Hebert, 20<sup>th</sup> February. 1841

Tho<sup>s</sup> S. Parkston

Day & Haghe Lithog<sup>rs</sup> to the Queen

PATEN

Fig 3

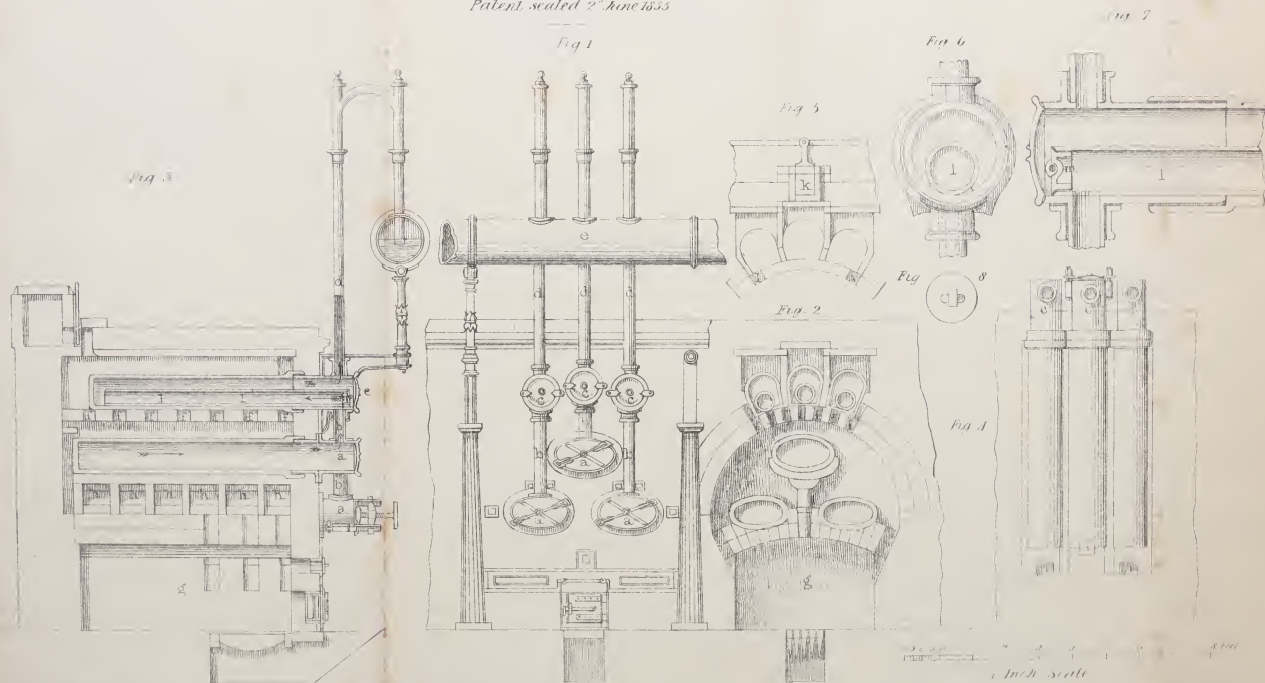


The S Peckston

PLAN ELEVATION AND SECTION  
of the  
PATENT GAS REGENERATORS & FURNACE  
John Malam, Patentee

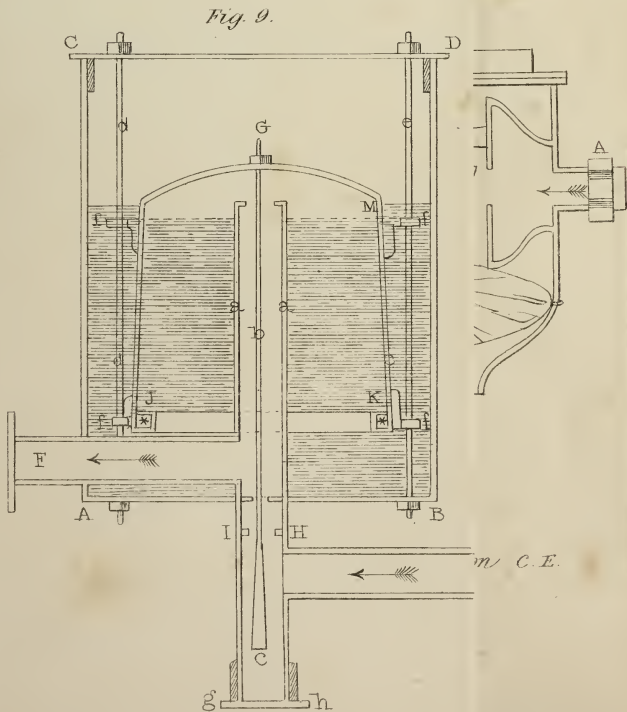
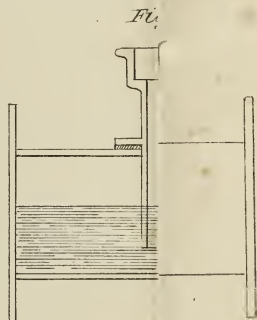
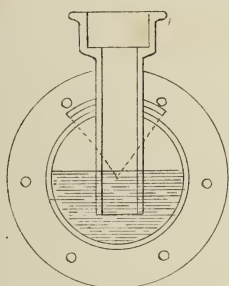
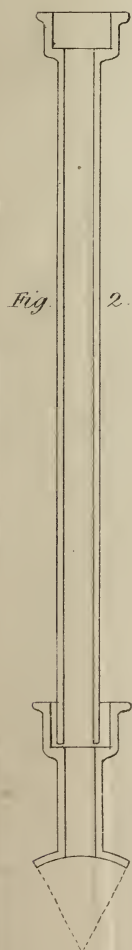
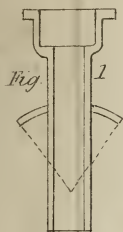
Patent sealed 2<sup>d</sup> June 1853

Plate 21



Theo. S. Peckston

Printed and Published by J. Peckston, 11, Abchurch Lane, London, E.C.



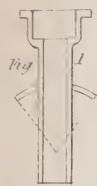


Fig. 1



Fig. 3.

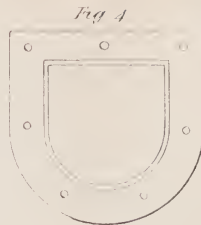


Fig. 4

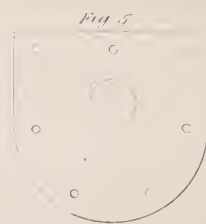


Fig. 5



Fig. 2

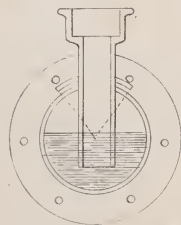


Fig. 6

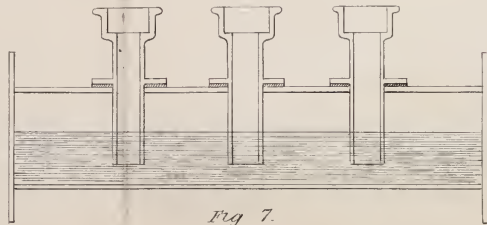


Fig. 7.

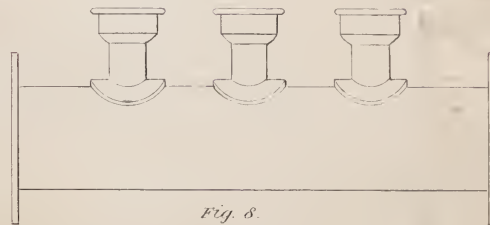


Fig. 8.

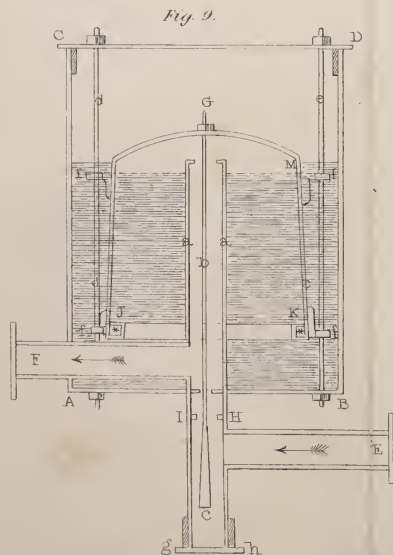


Fig. 9.

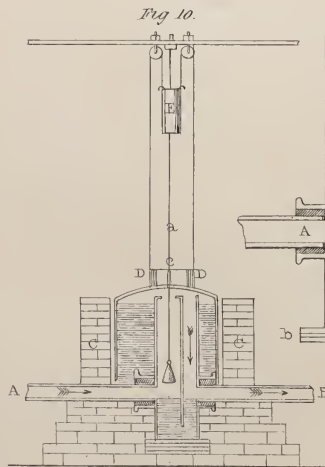


Fig. 10.

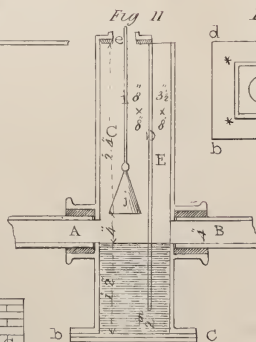


Fig. 11

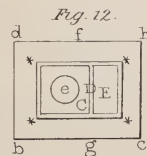


Fig. 12.



Fig. 13

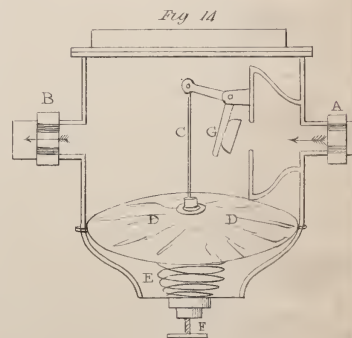
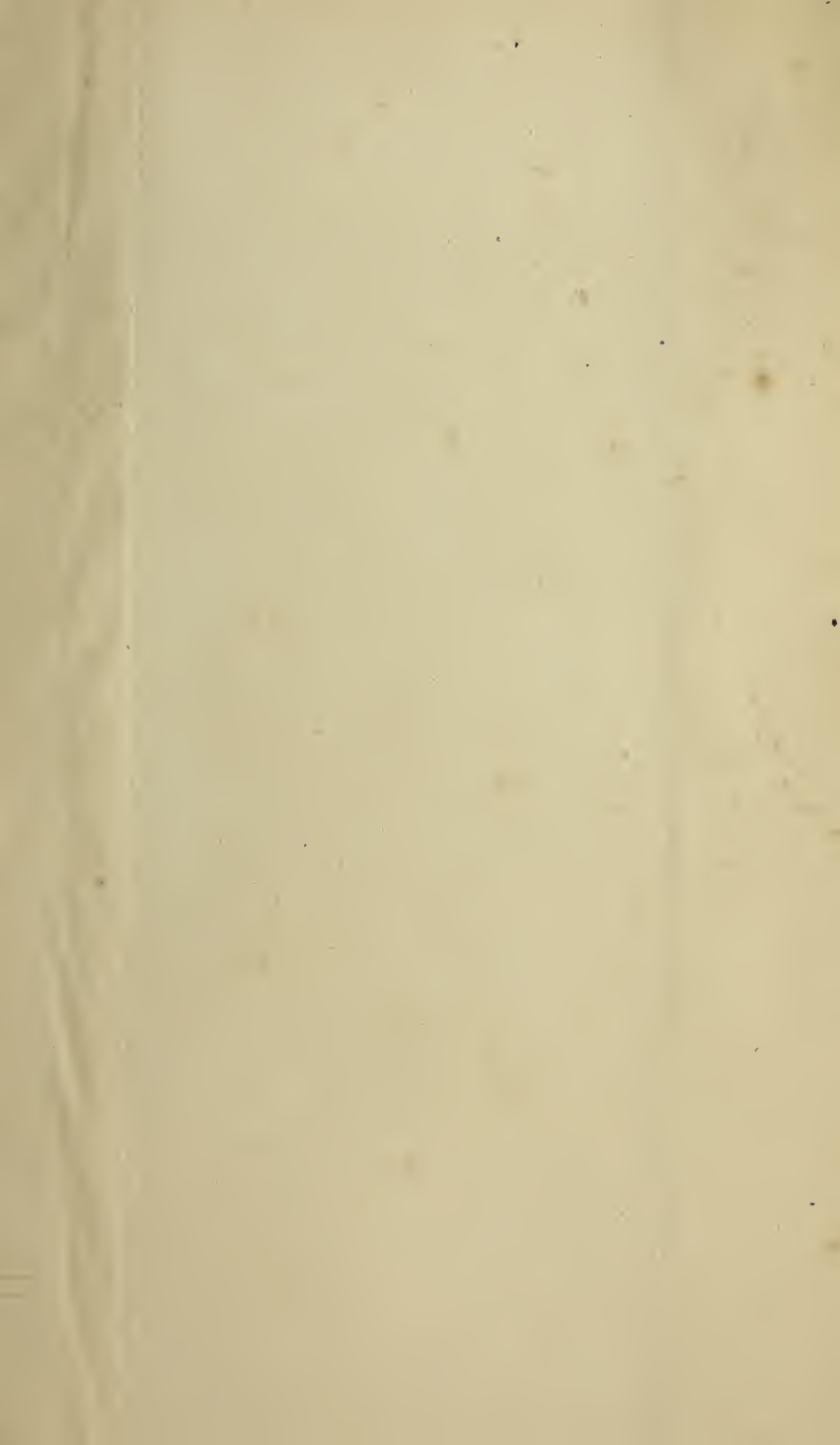
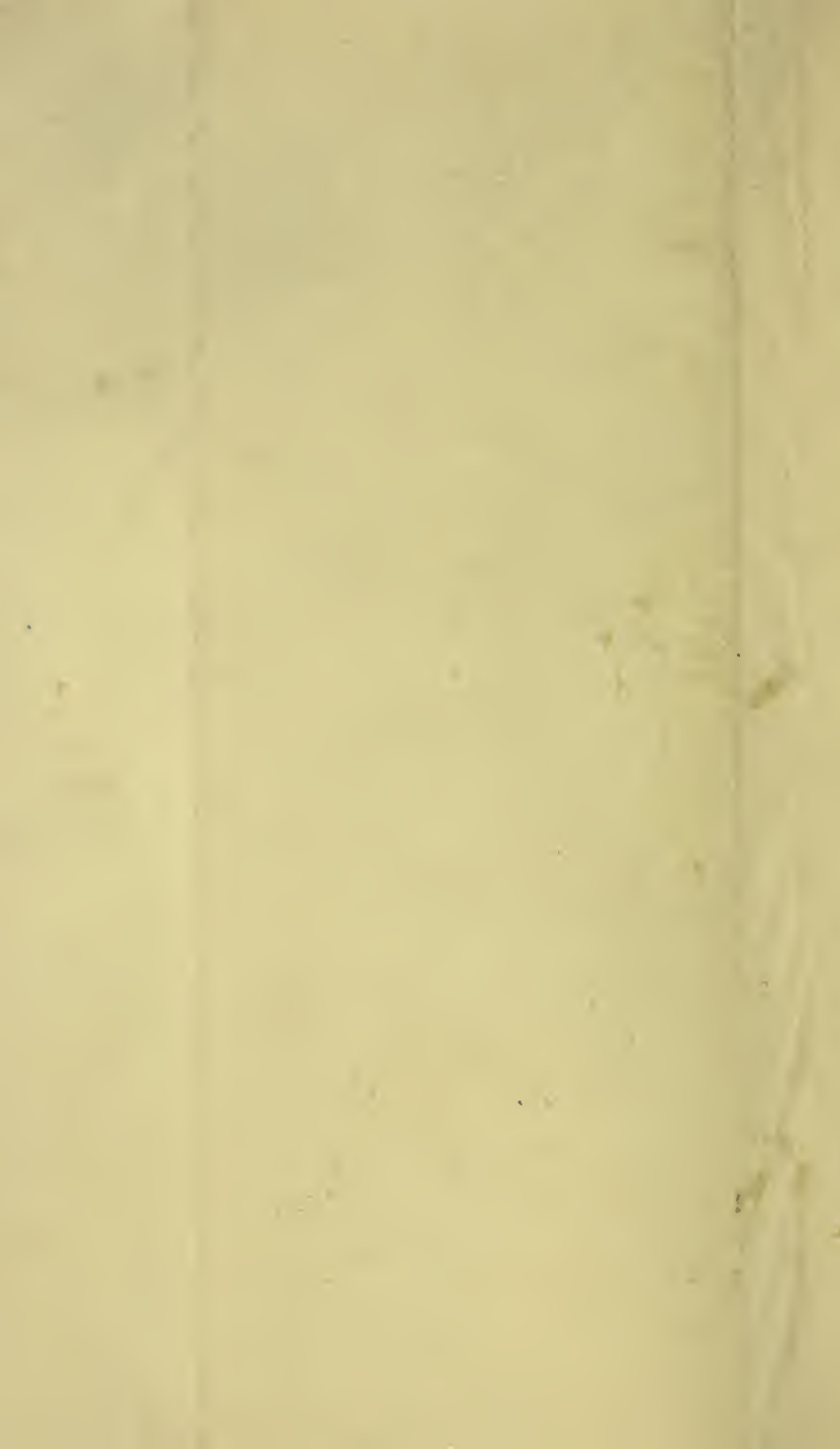


Fig. 14

Thos S Peckston C E

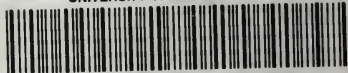
London: Pub<sup>d</sup> by E Herbert, 20<sup>th</sup> Feb<sup>y</sup> 1841







UNIVERSITY OF ILLINOIS-URBANA



3 0112 056239137

